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COMPARATIVE ANALYSIS
OF
OPERATIONAL FORECASTS
VS
ACTUAL WEATHER CONDITIONS
IN
AIRLINE FLIGHT PLANNING

VOLUME III



PRC SPEAS

DIVISION OF PRC PLANNING AND ECONOMICS, INCORPORATED

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16. Abstract A study was conducted on the impact of more timely and accurate weather data on airline flight planning with the emphasis on fuel savings. This volume of the report discusses the results of Task III of the four major tasks included in the study. Task III compared flight plans developed on the Suitland forecast with actual data observed by the aircraft (and averaged over 10 degree segments). The results showed that the average difference between the forecast and observed wind speed was 9 kts. without considering direction, and the average difference in the component of the forecast wind parallel to the direction of the observed wind was 13 kts. - both indicating that the Suitland forecast underestimates the wind speeds. The Root Mean Square (RMS) vector error was 30.1 kts. The average absolute difference in direction between the forecast and observed wind was 26 degrees and the temperature difference was 3 degrees Centigrade. These results indicate that the forecast model as well as the verifying analysis used to develop comparison flight plans in Tasks I and II was a limiting factor and that the average potential fuel savings or penalty are up to 3.6 percent depending on the direction of flight.					
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1. INTRODUCTION

PRC Speas, assisted by David R. Bornemann Associates, Inc., has conducted analyses of flight plan data for the National Aeronautics and Space Administration-Lewis Research Center under Contract #NAS3-22748.

The objective of these analyses was to assess the potential improvements in fuel savings which may be possible from improved meteorological data. Flight plans calculated from prescribed input parameters and meteorological data sets were used as quantitative indicators of differences in fuel burn and other relevant parameters. Flight plan data were provided through the cooperation of two airlines which will be referred to as "BLUE Airlines" and "RED Airlines" throughout this report in order to maintain anonymity.

The work program under this contract was divided into four tasks. This volume of the final report presents the findings of Task III which involved comparisons of actual flight plan winds and temperatures from an operational forecast with the actual winds and temperatures observed by flights equipped with an Aircraft Integrated Data System (AIDS).

Subsequent sections of this volume describe the analysis methodology and the results for Task III.

2. SUMMARY

The Task III analysis compared actual wind and temperature observations taken by AIDS equipped aircraft during eight months of 1979 with data from the flight plans used by those flights. The flight plans were based upon the NWS forecasts valid near the time the flights operated and were computed on the RED or BLUE Airlines flight planning systems. Flight plans for flights of the other airlines that use the BLUE Airlines system were also included in this analysis.

The objective of the Task III analysis was to determine differences that existed between the forecast winds and temperatures and those actually observed by the aircraft. In Task I, differences were determined (measured by fuel burn, flight time and air miles) between the forecast and the actual as represented by the NWS forecast and analysis models, after the data were subjected to the editing, smoothing, and other adjustments inherent in the model.

The key findings in Task III were:

- Based on analysis of 2,430 flight segments when the flight plan winds and temperatures based upon the NWS forecast were compared to actual data observed by the aircraft and averaged over 10 degree segments, difference between the forecast and observed wind speed was 9 kts., the direction difference averaged 26 degrees and the average temperature difference was 3°C. The average difference in the component of the forecast wind parallel to the direction of the

observed wind was 13 kts. The Root Mean Square (RMS) vector error was 30.1 kts. When the wind is always from the direction with maximum impact on the direction of flight a 13 kt. error results in fuel burn and time penalties of up to 15 minutes and 2,835 kg (932 gal.) of fuel for the average B747 flight. These flight segments were from operational routes which were not minimum fuel tracks and may not have been in the area of maximum wind and thus actual errors may be larger.

- Although BLUE and RED Airlines data agreed that the absolute value of the average temperature errors was 3°C, BLUE found the temperatures warmer than forecast while RED found them colder than forecast. Similarly, BLUE found the wind direction forecast error toward decreasing azimuthal directions while RED found errors toward increasing azimuth eastbound and decreasing westbound, indicating that weather data interpolation errors probably exist in one or both flight planning systems.

Computer programs were developed to extract the wind and temperature data from the flight plans and AIDS tapes, reduce them to comparable flight segments, and produce statistics on the differences between the forecast and actual winds and temperatures. While the flight plan winds and temperatures were normally already available as averages of ten degree longitude segments, the AIDS observations were typically spaced at 200 km intervals and averages for 10 degree segments had to be developed.

A cubic spline function was used to represent the AIDS flight's wind direction, speed, temperature and latitude as a continuous function of longitude along the flight path. The discrete values of these parameters were then determined for each five degree meridional crossing - i.e., 50W, 45W, 40W, 35W, etc. Average values for the ten degree segment were then determined weighting the midpoint twice the weight of each endpoint.

Segment data were checked for matches of month, day, flight number, origin, destination position and flight level. Segments for which the AIDS flight did not match the operational flight plan were discarded.

2.1 MAGNITUDE OF FORECAST DIFFERENCES

Matching data from AIDS flights and flight plans were found for 2,430 segments distributed regionally as follows:

	<u>BLUE Airlines</u>	<u>RED Airlines</u>
Eastbound North Atlantic	394	358
Westbound North Atlantic	696	736
Eastbound Polar	4	79
Westbound Polar	13	109
Eastbound Mid-Atlantic	9	
Westbound Mid-Atlantic	32	

Differences between the flight plans and AIDS data per flight segment, and thus between the forecast and the observed, are summarized below:

	<u>BLUE Airlines</u>	<u>RED Airlines</u>
<u>Average Algebraic Difference</u>		
Wind Direction	-5 deg	+1 deg
Wind Speed	-9 kts	-5 kts
Temperature	-2°C	+1°C
<u>Average of Absolute Values of Differences</u>		
Wind Direction	29 deg	20 deg
Wind Speed	14 kts	13 kts
Temperature	3°C	3°C
<u>Average Difference in Component of Forecast Wind Parallel to Observed Wind</u>	16 kts	8 kts
<u>RMS Vector Error</u>	33 kts	24 kts

Using data from Task I on average North Atlantic flight times and fuel burns, it was determined that if the wind were always from the direction with maximum impact on the direction of flight this error results in fuel burn and time penalties of up to 15 minutes and 2,835 kg of fuel for a B747 flight. This fuel burn penalty, or potential savings, amounts to 3.6 percent of the fuel burn for the flight.

Since the criteria for matching AIDS flights and flight plans resulted in some 70 to 80 percent of segments being rejected, a supplemental analysis was conducted with relaxed criteria to expand the size of the sample. In this second run segments with flight level differences of plus or minus 2,000 feet between the flight plan and AIDS data were not rejected. This resulted in a sample of 1,788 BLUE Airlines segments and 1,282 RED Airlines segments for a total of 3,070 segments. Even though the sample increased by 72 percent the average forecast error only changed by 0.5 degrees on wind direction, 0.2 kts. on speed, and 0.34°C on temperature, leading to the conclusion that the original sample was large enough to be representative of the real world even though many data had to be rejected.

2.2 SIGN OF FORECAST DIFFERENCES

Since the average algebraic differences between the forecast values and the observed values were determined by subtracting the observed value from the forecast value, the algebraic sign of the differences provided further data on the forecast errors.

For the North Atlantic region the means of the algebraic differences between the operational flight plan and the AIDS data were:

	<u>Temperature (°C)</u>	<u>Wind Direction (deg)</u>	<u>Speed (kts)</u>
<u>BLUE Airline</u>			
Eastbound	-2.28	-5.35	-8.27
Westbound	-2.53	-4.17	-8.97
<u>RED Airline</u>			
Eastbound	+1.97	+1.94	-6.39
Westbound	+1.69	-2.04	-4.24

For both airlines the average wind speed differences were always negative, meaning the AIDS winds were stronger and implying that wind speeds were underestimated which confirms the findings of the other tasks in this study.

Negative temperature differences mean temperatures were warmer than forecast and the findings on temperature were somewhat incongruous. Even though both airlines' data agreed that the temperature forecasts were in error by approximately 3°C, the BLUE Airlines data showed the temperatures warmer than forecast while the RED data implied temperatures were colder than forecast (positive differences). Regarding wind direction, negative differences mean the forecast wind is from a lower azimuthal direction than the actual wind, or in other words, considering

that the average wind direction should be from 270 degrees, negative differences suggest actual winds more northwesterly than forecast and positive differences suggest actual winds more southwesterly than forecast. On wind direction, the BLUE Airlines differences were always negative while the RED Airlines differences (for the larger North Atlantic sample) were positive eastbound and negative westbound. No information available to PRC Speas suggests an explanation for these latter two incongruous findings and it is suspected that they are the result of features peculiar to the weather data interpolation techniques in use by the RED or BLUE Airlines or both.

3. ANALYSIS METHODOLOGY

The objective of Task III was to determine differences that existed between actual winds and temperatures and those derived from the National Weather Service forecasts by airline flight planning systems. In Task I airline flight plans were used to determine differences that existed between the forecast and the verifying analysis as depicted by the NWS models, the Seven Level Primitive Equation Model and the Flattery Analysis Model, but this approach could not detect anomalies that may have been introduced by the flight planning systems or the NWS forecast model. Here, the forecast winds and temperatures from operational flight plans were compared directly to winds and temperatures observed by AIDS equipped aircraft and the results may represent the most accurate measure to date of the differences between expected wind/temperature fields and those actually encountered.

3.1 DATA SOURCES

The data included in Task III were collected for NASA during 1979 by eight international airlines. Flight plans and AIDS data were collected from the seven airlines that use the BLUE Airlines flight planning system, and from RED Airlines. AIDS automatically collected on-board the aircraft and stored on magnetic tape, readings of position, altitude, temperature, wind velocity and time. Since AIDS was coupled to the

Inertial Navigation System (INS) and other on-board computers, the data gathered by AIDS were extremely accurate.

Data collected by the airlines using the BLUE system were collected during the first four months of 1979 and for August through November. Data from RED Airlines flights were collected for the same months except that July was included and November was not. However, no RED AIDS data were available for January, February and March. Therefore, the analysis of RED Airlines data was based on the five months - April, July, August, September and October.

Data were collected by the eight airlines for some 250 days by some 80 AIDS equipped aircraft. Since most of the airlines were principally North Atlantic operators, most of the AIDS data were for the North Atlantic, Middle Atlantic, Caribbean or Polar regions. However, some data were collected by flights through the Mid East or Far East.

Flight plans for RED Airlines AIDS equipped flights were collected for NASA on magnetic tape throughout the year. Copies of all BLUE Airlines flight plans produced on the BLUE flight planning system were also collected. Raw AIDS data from the various airlines were collected, quality controlled and reformatted by a government agency as part of a global weather experiment.

3.2 DATA NORMALIZATION

NASA specified that the Task III analysis should compare flight plan segments of 10 degrees of longitude with corresponding AIDS segments. Therefore, the principal data reduction task was the normalization of the flight plan and AIDS data in to common 10 degree segments.

For most off-airways segments flight plan data were already presented in 10 degree segments. For these segments the forecast winds and temperatures could be read directly from the RED Airlines flight plans and derived from the wind data on the BLUE Airlines plans. These winds and temperatures represent the average values for the 10 degree segment as determined by the respective flight planning system. Since each of these airlines use a different algorithm for interpolation between data points, it is not likely that both would develop identical winds and temperatures for any given segments. The values they do develop, however, must be considered to be reasonably representative of the average segment winds and temperatures determined from the NWS forecast, and represent the techniques which are used by many of world's airlines.

For airways segments identified on the flight plans by navigational aids or other checkpoints, 10 degree longitude segments were not clearly defined. Latitudes and longitudes locating airways checkpoints were not included on many of the flight plans making it impossible to define a 10 degree segment on airways. It may have been possible with manual

intervention in the otherwise automated analysis process to define airways segments of approximately 10 degrees of longitude. However, due to such things as multiple use of the same checkpoint identification in different parts of the world and the highly variable length of airways segments, this analysis would have been very difficult and would have added little additional data since most of the segments were off airways.

Normalizing the AIDS data to 10 degree segments was a more complex problem. AIDS data could not be compared directly, since AIDS reporting points did not coincide with flight plan checkpoints. Although both sets of data followed the same track (or else the flight was rejected as a mismatch), the AIDS data were captured every 13 or 14 minutes at random positions along the route. On a typical North Atlantic flight, there would be about 20 AIDS observations between 80W and 10W longitude. By contrast, the corresponding flight plan would include only six or seven checkpoints, normally at ten degree meridians and whole degrees of latitude. Before any meaningful data comparisons could be made, it was necessary to develop a technique to "map" the AIDS observations onto the flight plan checkpoints.

After considering linear and geographic interpolation schemes similar to those used in the RED, BLUE and other airline flight planning systems it was decided that the AIDS wind direction, speed, temperature and latitude should be represented as continuous functions of longitude along the

flight path and representative segment values determined from these functions.

An interpolation technique was therefore required to develop simulated AIDS data at the flight plan positions, i.e., ten degree meridians and whole degrees of latitude, for purposes of comparison. Normal curve fit routines, such as multiple regression or Box-Jenkins techniques, were not deemed suitable for this purpose; these techniques are generally used to forecast or extrapolate data outside the range of observations; however, this task required careful interpolation of data between observations. The Polynomial approximation is considered to be the best technique for this purpose.

The AIDS data elements of interest (temperature, wind speed, and wind direction) all have the property that they are "continuous", i.e., are gradually changing over time (or distance) and do not have discontinuities or gaps in the data. Temperatures, wind velocities and directions change gradually and do not jump from one value to another. For this type of data, cubic polynomials have been found to produce the best interpolations; cubic polynomials produce a continuously varying curve, or "spline", through the data observations in such a way as to minimize errors in curvature. This technique has been previously applied to meteorological conditions.

This "cubic spline" technique was applied to all AIDS flights with at least 14 data reports, and for which a corresponding flight plan existed. Longitude was used as the independent variable in the spline development process, so that data (temperature, east-west and north-south component of the wind) could be derived for any longitude. These data were computed for every five degrees of longitude, and then a "1-2-1" weighting technique was applied to calculate the average value for a given ten degree segment so as to correspond to the segments on the flight plan. (The 1-2-1 weights are simply Romberg integration with two sub-intervals.) For example, the calculation of the average temperature for a segment from 30W to 40W longitude was based on single weighting of the derived temperatures at 30W and 40W combined with a double weighting of the 35W temperature.

The following table of wind speeds and temperature, based on AIDS data for a trans-Atlantic flight, demonstrates the cubic spline technique:

<u>WIND SPEED (KTS)</u>			<u>TEMPERATURE (-°C)</u>	
<u>Spline</u>	<u>AIDS</u>	<u>Lat/Long</u>	<u>AIDS</u>	<u>Spline</u>
--	34	44N/80W	47	--
62	45,59	75W	47,47	47
93	65,86	46N/70W	47,48	48
102	110	65W	48	47
68	95	49N/60W	46	43
56	60	55W	42	43
52	--	51N/50W	50,56	50
100	80,110	45W	56	56
91	112	52N/40W	55,57	55
76	90,79	35W	58	57
53	70	53N/30W	57,59	57
45	51,46	25W	59	59
65	49	54N/20W	57,51	57
64	66,63	15W	50	50,51
84	72	55N/10W	47,49	47
107	87,119	5W	53	49
100	107	54N/0W	54	53

These derived spline values were then subjected to the 1-2-1 weighting techniques to produce the following segment averages:

44N/80W to 46N/70W	64 kts, -47°
46N/70W to 49N/60W	92 kts, -46°
49N/60W to 51N/50W	58 kts, -45°
51N/50W to 52N/40W	86 kts, -54°
52N/40W to 53N/30W	74 kts, -57°
53N/30W to 54N/20W	52 kts, -59°
54N/20W to 55N/10W	70 kts, -51°

These calculated segment averages were then compared to the corresponding values on the computer flight plan. In accordance with standard meteorological practice, all calculations involving wind were performed on the scalar components of a given wind velocity; these scalar components were then recombined to produce the appropriate wind vector.

Having resolved the AIDS data into 10 degree segments, it was then necessary to match AIDS segments with the appropriate flight plans and verify that the routes, flight levels, and forecast times were comparable.

The BLUE Airlines flight plans were collected by copying the outgoing queue of all flight plans produced by the system and periodically dumping the queue onto magnetic tape. Thus, these tapes included many plans that were not relevant to this analysis which had to be removed from the data during preliminary processing. A more significant problem resulted from the presence of more than one flight plan for the same flight. When several flight plans existed for the same flight number and date the plan that the aircraft actually followed had to be determined first by comparing the plans to the AIDS route. Of course, in some case the aircraft actually followed a route other than the one in any of the plans. In these cases data were salvaged for that portion of the route which did match.

A similar procedure was followed for the RED Airlines data. However, in this case only plans from AIDS flights were included on the tape.

Having matched operational airline flight plans and AIDS flights a final check on flight level and routing was made. Flight plan segments with flight levels or checkpoints that did not match the AIDS data were discarded initially. However, when it was determined that a large number of segments was rejected, a second run was made which retained all flight plan segments whose flight levels were within plus or minus 2,000 feet of the AIDS flight levels.

4. FINDINGS

The results of the comparisons between the AIDS data and the corresponding flight plan segments based on the operational forecast are presented in this section. Results from plans developed by the BLUE and RED systems are presented separately as are findings by region and direction of flight.

4.1 BLUE AIRLINES FINDINGS

In the initial run, matching data from AIDS flights and BLUE flight plans were found for 1,148 segments. Data for approximately 11,000 AIDS segments were collected by the seven airlines using the BLUE Airline flight planning system. Therefore, matching data were found for some 10 percent of the segments.

Based upon a sampling of the data it was determined that about 16 percent of the segments could not be matched because the AIDS flight levels or routings were not the same as the planned routings or flight levels. The remaining 74 percent of AIDS segments could not be matched to flight plan segments because a corresponding flight plan could not be found. It was eventually determined that the BLUE flight planning system output queue was not dumped onto the magnetic tape frequently enough and flight plans were lost during 24 to 48 hour periods. It is estimated that this

resulted in the loss of up to 50 percent of the otherwise valid segment comparisons.

The regional and directional distribution of the 1,148 valid segment comparisons was as follows:

North Atlantic Eastbound	394
North Atlantic Westbound	696
Polar Eastbound	4
Polar Westbound	13
Mid-Atlantic Eastbound	9
Mid-Atlantic Westbound	32

As in Tasks I and II, the results of the segment comparisons were presented in the form of histograms which depict the number of occurrences of a given temperature or wind difference between the flight plan segments and the AIDS derived segments. These data are included in Appendix A to this volume of the report for both BLUE and RED Airlines results. The data in the Appendix present the findings by direction of flight and region, and include the algebraic mean of the differences as well as the variance, standard deviation and 90 percent confidence limits for the temperature difference, the wind direction difference and the wind speed difference, the difference in speed between the component of the forecast wind parallel to the actual wind and the actual wind, the similar difference for the component perpendicular to the actual wind

(the cross-component), and the magnitude of the vector difference. The RMS of the Vector Error is also included for each region, airline and direction of flight group at the end of Appendix A.

Figure 4-1 summarizes the BLUE Airlines results by region and direction of flight. The results are presented in several forms so that they may be meaningful to the widest audience. It was believed that, traditionally, pilots and others concerned with flight planning refer to wind "forecast error" as the differences between the forecast and observed wind, as defined by the differences between the two scalar quantities wind directions and wind speed. Thus, if the forecast wind were 290 degrees at 100 kts. and the observed wind were 270 degrees at 120 kts., one would say the "forecast error" was 20 degrees and 20 kts. Using this definition of "forecast error" the mean forecast error for all segments was found to be 28.5 degrees and 13.8 kts for the wind and 2.9°C for the temperature.

Results according to the above definition are identified in Figure 4-1 as the "Algebraic Differences" which include the algebraic sign of the average differences between the forecast value and the observed value, and the "Absolute Value of Differences" which eliminate the sign or directional nature of the differences.

Figure 4-1

TASK III RESULTS
AVERAGE SEGMENT DIFFERENCES BETWEEN FORECAST AND ACTUAL
BLUE AIRLINE DATA

	NORTH ATLANTIC		POLAR		MID ATLANTIC		ALL
	Eastbound	Westbound	Eastbound	Westbound	Eastbound	Westbound	
<u>ALGEBRAIC DIFFERENCES</u>							
Wind Direction (degrees)	-5.4	-4.2	-69.0	-17.9	-13.0	0.9	-4.5
Wind Speed (knots)	-8.3	-9.0	-18.0	-11.4	-14.4	-5.0	-8.7
Temperature (°C)	-2.3	-2.5	-1.0	-1.7	+0.4	-1.0	-2.4
<u>ABSOLUTE VALUE OF DIFFERENCES</u>							
Wind Direction (degrees)	22.0	29.8	109.0	43.3	57.9	56.8	28.5
Wind Speed (knots)	15.3	13.0	19.5	16.3	14.4	9.4	13.8
Temperature (°C)	3.0	3.0	1.5	2.2	2.7	1.5	2.9
<u>DIFFERENCE IN PARALLEL COMPONENT (knots)</u>	-13.6	-17.0	-34.3	-19.8	-17.8	-10.5	-16
<u>DIFFERENCE IN CROSS COMPONENT (knots)</u>	-4.4	-3.0	-5.0	-8.7	-2.8	0	-3.5
<u>MAGNITUDE OF VECTOR DIFFERENCE (knots)</u>	26.2	24.9	35.5	26.5	22	18.5	25.2
<u>RMS OF VECTOR ERROR</u>	33.7	33.6	38.3	31.0	23.3	20.3	33

Source: PRC Analysis of BLUE Airline Data

Using data from Task I on average North Atlantic flight times and fuel burns, it was determined that if the wind were always from the direction with maximum impact on the direction of flight this error results in fuel burn and time penalties of up to 15 minutes and 2,835 kg of fuel for a 8747 flight. This fuel burn penalty, or potential savings, amounts to 3.6 percent of the fuel burn for the flight.

However, this finding may be misleading if taken out of context because, in reality, elimination of the forecast error would result in a new route selection for the flight on the improved forecast which would maximize the savings. In this analysis the route is the same on the AIDS observed weather as on the forecast weather.

While the presentation of "forecast errors" as defined above will be meaningful to some, if not most readers, it is not mathematically correct since the wind is a vector and one cannot refer to the independently determined differences (or error) between the scalar components as the difference between the vectors. Therefore, in order that the results presented here may be related to other mathematically sound forecast verification data that may be more meaningful to meteorologists, the other quantities presented in Figure 4-1 were determined.

It is interesting to consider the meaning of the findings regarding the mean of the algebraic differences. Reference to Figure 4-1 shows that

for both directions, and for nearly all combinations of region and forecast parameter especially on the North Atlantic where there is a substantially higher number of observations, all of the means are negative. Since these differences are obtained by subtracting the AIDS derived value from the flight plan value, the negative numbers mean that the AIDS values were larger, on the average. Since the AIDS data represent the actual and the flight plans represent the forecast, these data show that wind speeds are higher than forecast (again confirming the findings from the other tasks) and temperatures are warmer than forecast on the average. Regarding wind direction, negative differences mean the forecast wind is from a lower azimuthal direction than the actual wind, or in other words, considering that the average wind direction should be from 270 degrees, negative differences suggest actual winds more northwesterly than forecast.

4.2 SUPPLEMENTAL BLUE AIRLINES FINDINGS

Since so many segments were rejected because a corresponding flight plan could not be found in the BLUE Airlines data, it was decided that the analysis would be rerun with a relaxation of the criteria for matching segments. It was assumed that, if a substantially higher number of segments could be included in the sample without changing the result significantly, the sample was large enough in the first place to represent the real world and the loss of some of the BLUE Airlines data did not distort the findings.

For the reanalysis run the requirement that segment flight levels match was changed to a requirement that the AIDS flight segment be within plus or minus 2,000 feet of the flight plan segment. A match was still required on the beginning and end points of the segment. Under these conditions matches were found for 1,788 segments distributed as follows:

North Atlantic Eastbound	581
North Atlantic Westbound	1,142
Polar Eastbound	4
Polar Westbound	14
Mid-Atlantic Eastbound	12
Mid-Atlantic Westbound	35

A summary of the mean of the differences of the absolute values is presented in Figure 4-2 for each region and direction along with the differences between these data and the data from Figure 4-1 which used the more stringent flight level matching criterion.

The differences of 0.5 degrees on wind direction, 0.2 kts. for wind speed, and 0.3°C for temperature are negligible.

As might be expected when more comparisons from different flight levels are included, the averages of the algebraic differences also changed, but by relatively small amounts. For the North Atlantic region, each of the forecast parameters had larger negative differences with the larger

Figure 4-2

TASK III RESULTS
SEGMENT FORECAST ERRORS
BLUE AIRLINE DATA

MEAN OF THE ABSOLUTE VALUES OF DIFFERENCES BETWEEN FORECAST FLIGHT PLAN
SEGMENTS AND AIDS DERIVED SEGMENTS
(RELAXED FLIGHT LEVEL MATCHING CRITERION)

	WIND		TEMPERATURE
	Direction (deg)	Speed (kts)	(°C)
Eastbound North Atlantic	22.8	15.5	3.4
Westbound North Atlantic	30.7	13.3	3.2
Eastbound Polar	0	0	0
Westbound Polar	42.6	15.7	2.4
Eastbound Mid Atlantic	48.8	13.5	2.4
Westbound Mid Atlantic	54	9.4	1.5
All Segments	29.0	14.0	3.2

DIFFERENCES BETWEEN ABOVE VALUES AND MATCHED FLIGHT LEVEL VALUES
(FIG. 4-2 DATA MINUS FIG. 4-1 DATA)

Eastbound North Atlantic	0.8	0.2	0.4
Westbound North Atlantic	0.9	0.3	0.2
Eastbound Polar	0	0	0
Westbound Polar	0.7	0.6	0.2
Eastbound Mid Atlantic	9.1	0.9	0.3
Westbound Mid Atlantic	2.8	0	0
All Segments	0.5	0.2	0.3

Source: PRC Speas Analysis of BLUE Airline data.

number of observations, implying that the forecast errors were larger, which would be expected when different flight levels are compared.

4.3 RED AIRLINES FINDINGS

Matching AIDS data and flight plan data were found for 575 segments which were included in the statistical analysis. This represents 22 percent of the AIDS derived segments.

A sample of six day's data was reviewed manually to determine why no matching segments were found for the remaining 78 percent of AIDS segments. Based on this sample:

- 28 percent were airways segments;
- 16 percent were at different flight levels;
- 5 percent had different flight numbers and could not be identified positively with the AIDS flight;
- 7 percent were on a different route;
- 22 percent had no corresponding operational flight plan for the same date and flight number. (The possibility that these flight plans had the wrong flight date was checked but the flights did not exist on the preceding or following day either.)

The regional and directional distribution of the 575 segment comparisons was as follows:

North Atlantic Eastbound	165
North Atlantic Westbound	327
Polar Eastbound	36
Polar Westbound	47

The RED Airlines results are summarized in Figure 4-3. As with the BLUE Airlines results, more detailed data are included in Appendix A.

The forecast errors indicated by the RED Airlines data are quite similar to those from the BLUE Airlines data. The average segment temperature error is almost identical at 3°C. The wind speed error is slightly smaller at 12.9 knots. However, the average wind direction error is nearly ten degrees less at 19.6 degrees. The RMS of the vector error for the RED data was 24.0 and the magnitude of the vector difference was 20.2 kts.

While the data in Figure 4-3 confirm that the magnitude of the forecast errors are comparable to those found in the analysis of the BLUE Airlines data, consideration of the algebraic differences shows some inconsistency between the findings for the two airlines.

The negative wind speed differences imply that actual wind speeds are normally higher than forecast - a finding consistent with the BLUE Airlines data and with the findings throughout the other tasks in this study. The predominantly positive temperature differences imply actual

Figure 4-3

TASK III RESULTS
AVERAGE SEGMENT DIFFERENCES BETWEEN FORECAST AND ACTUAL
RED AIRLINE DATA

	NORTH ATLANTIC		PGLAR		ALL
	Eastbound	Westbound	Eastbound	Westbound	
<u>ALGEBRAIC DIFFERENCES</u>					
Wind Direction (degrees)	+1.9	-2.0	-3.8	-2.6	-1.0
Wind Speed (knots)	-6.4	-4.2	-5.7	-9.2	-5.3
Temperature (°C)	+2.0	+1.7	-0.7	+0.4	+1.5
<u>ABSOLUTE VALUE OF DIFFERENCES</u>					
Wind Direction (degrees)	13.5	21.7	22.3	24.8	19.6
Wind Speed (knots)	15.3	11.5	12.4	14.0	12.9
Temperature (°C)	3.1	3.0	2.8	2.7	3.0
<u>DIFFERENCE IN PARALLEL COMPONENT (knots)</u>	-9.2	-7.6	-8.7	-12.0	-8.0
<u>DIFFERENCE IN CROSS COMPONENT (knots)</u>	+3.4	-3.1	+0.6	-2.0	-0.9
<u>MAGNITUDE OF VECTOR DIFFERENCE (knots)</u>	24.0	18.7	18.1	19.0	20.2
<u>RMS OF VECTOR ERROR</u>	28.5	21.9	23.8	22.3	24.0

Source: PRC Analysis of RED Airline Data

temperatures colder than forecast and, as discussed earlier, positive wind direction differences mean winds from a lower azimuthal heading or more southwesterly than forecast while negative differences denote winds more northwesterly than forecast, or from a higher azimuthal heading. These data suggest two incongruous conclusions. First, even though both RED and BLUE agree that the average segment temperature forecast is in error by 3°C, one airline consistently finds the forecast temperatures too warm while the other finds them too cold. Second, wind direction forecast errors tend to be dependent on the direction of flight, according to the RED Airlines data.

Since the average direction errors are so small, the second conclusion may be merely a statistical quirk. If it is not, it cannot be explained by any information that was available to PRC Speas and it is suspected that it is the result of the weather data interpolation scheme used by RED Airlines. Similarly, there is no explanation for the BLUE Airlines' tendency toward larger and more northwesterly wind direction errors and it too must be the result of an inherent feature in the flight planning system.

Regarding the temperature errors, no explanation can be offered for the inconsistency and these must certainly be the result of the flight planning system's processing algorithm.

4.4 SUPPLEMENTAL RED AIRLINES FINDINGS

Although the supplemental run was conducted primarily because of the lost BLUE Airlines data, the RED data were also included in the rerun with the relaxed flight level criterion.

In the rerun 707 additional matching segments were found bringing the total to 1,282. These segments were distributed geographically as follows:

North Atlantic Eastbound	358
North Atlantic Westbound	736
Polar Eastbound	79
Polar Westbound	109

The results of the analysis with the supplemental data are summarized in Figure 4-4.

As with the BLUE Airlines data, the 120 percent increase in the number of segments compared did not change the results appreciably. The average wind direction error changed by 1.9 degrees, the speed changed by 0.4 kts. and the temperature changed by 0.4°C.

Figure 4-4

TASK III RESULTS
 SEGMENT FORECAST ERRORS
 RED AIRLINE DATA

MEAN OF THE ABSOLUTE VALUES OF DIFFERENCES BETWEEN FORECAST FLIGHT PLAN
 SEGMENTS AND AIDS DERIVED SEGMENTS
 (RELAXED FLIGHT LEVEL MATCHING CRITERION)

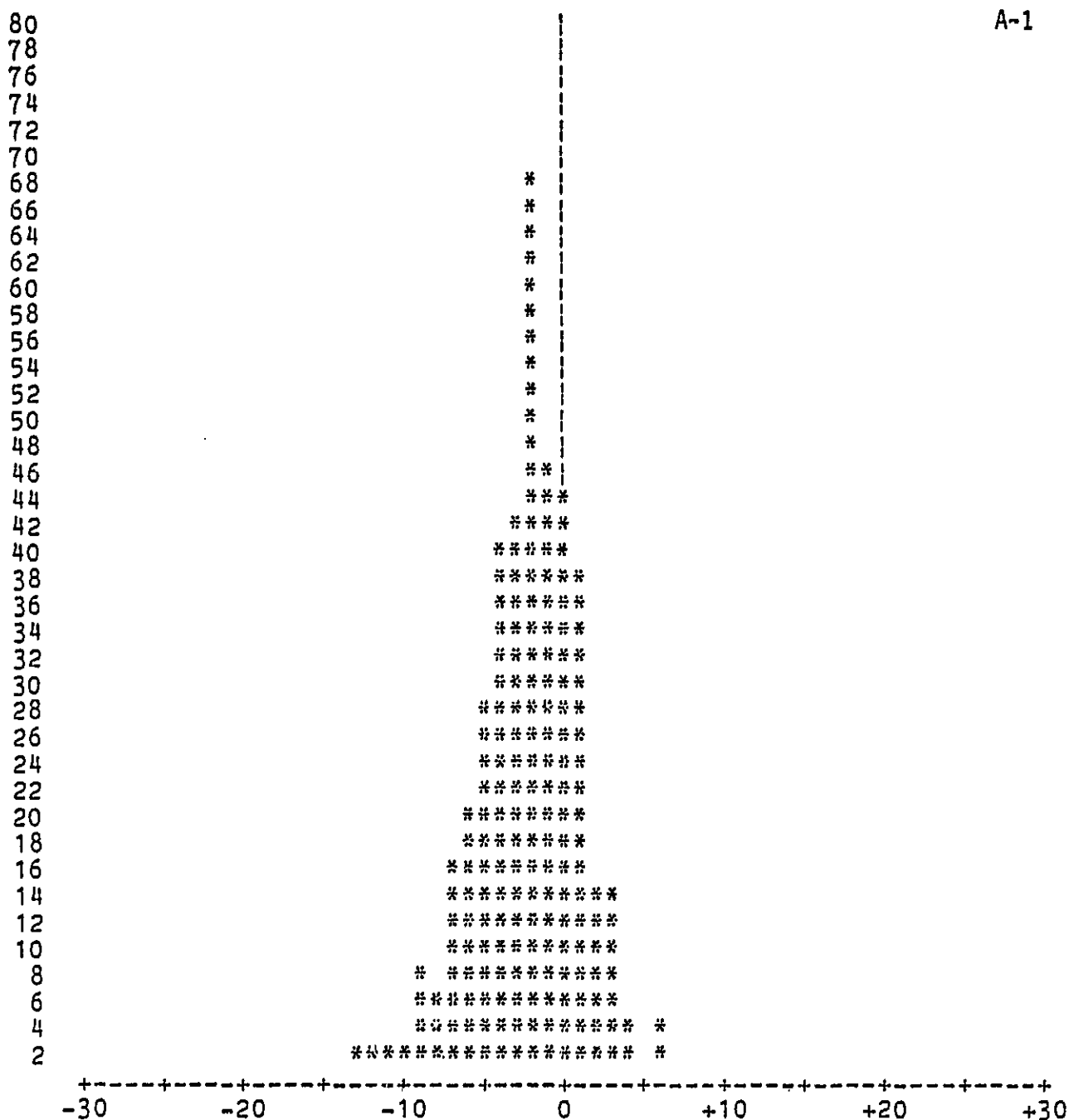
	WIND		TEMPERATURE
	<u>Direction (deg)</u>	<u>Speed (kts)</u>	<u>(°C)</u>
Eastbound North Atlantic	16	16.4	3.6
Westbound North Atlantic	22.8	12.0	3.4
Eastbound Polar	22.0	10.5	2.8
Westbound Polar	30.1	13.6	3.3
All Segments	21.5	13.3	3.4

DIFFERENCES BETWEEN ABOVE VALUES AND MATCHED FLIGHT LEVEL VALUES
 (FIG. 4-4 DATA MINUS FIG. 4-3 DATA)

Eastbound North Atlantic	2.5	1.1	0.5
Westbound North Atlantic	1.1	0.5	0.4
Eastbound Polar	0.3	1.9	0
Westbound Polar	5.3	0.4	0.6
All Segments	1.9	0.4	0.4

Source: PRC Speas Analysis of RED Airline data.

APPENDIX A
FINDINGS BY REGION, DIRECTION OF FLIGHT, AND AIRLINE



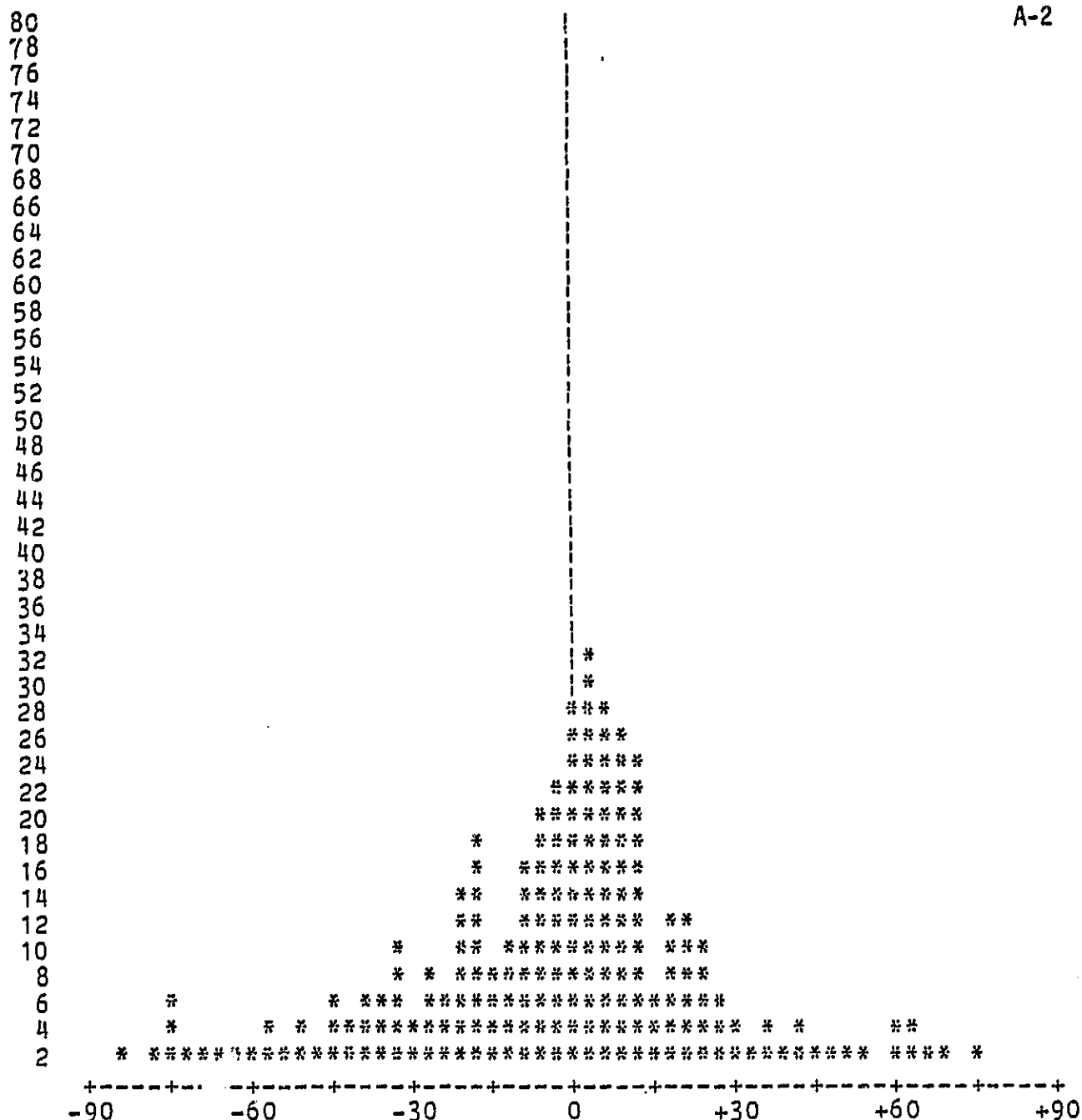
NUMBER OF OCCURRENCES BY DIFFERENCE

Temperature Difference in Degress Centigrade

Operational Segments MINUS AIDS Derived Segments

MEAN = -2.27664975
 VARIANCE = 9.91585072
 MEAN (ABSOLUTE DIF.) = 2.99746193
 STANDARD DEVIATION = 3.14894438
 90% CONFIDENCE LIMITS = -7.45666326 TO 2.90336376
 TOTAL OCCURRENCES = 394

CARRIER: BLUE DIRECTION: Eastbound REGION: North Atlantic



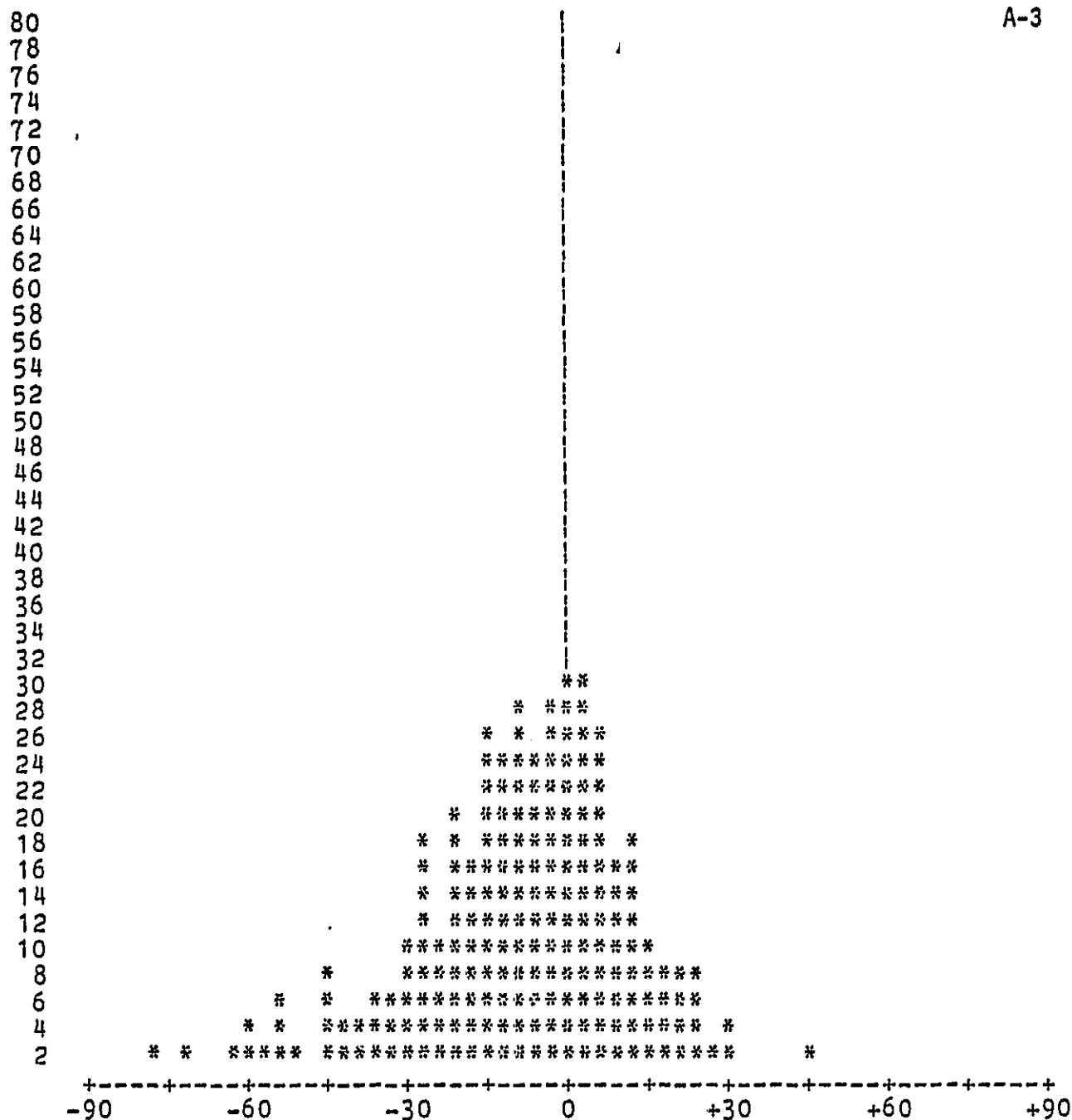
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Direction Difference in Degrees

Operational Segments MINUS AIDS Derived Segments

MEAN	=	-5.35279188	
VARIANCE	=	1076.98468	
MEAN (ABSOLUTE DIF.)	=	22.0228426	
STANDARD DEVIATION	=	32.8174447	
90% CONFIDENCE LIMITS		-59.3374885	TO 48.6319047
TOTAL OCCURRENCES	=	394	

CARRIER: BLUE DIRECTION: Eastbound REGION: North Atlantic



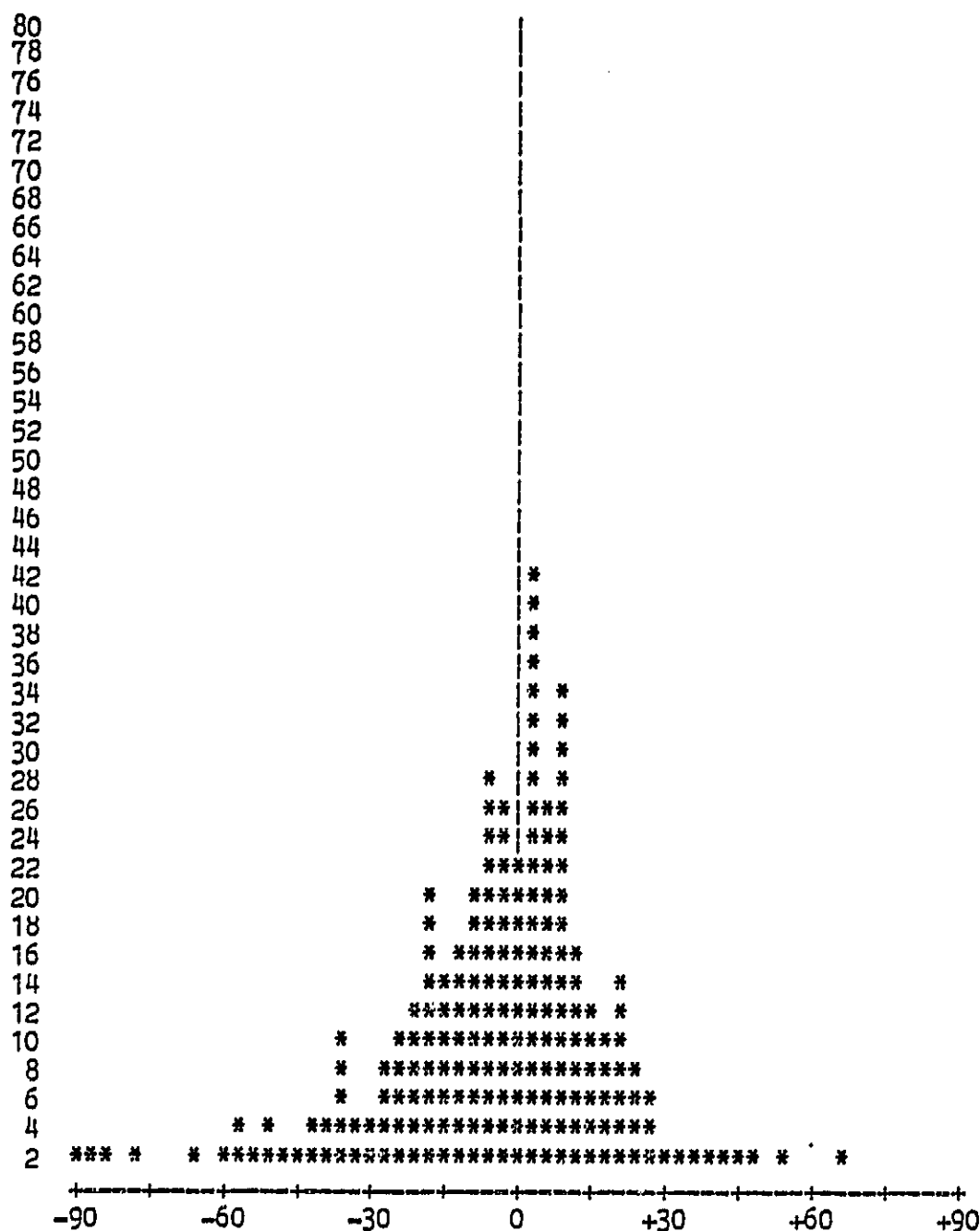
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Speed Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -8.27226463
 VARIANCE = 351.0989
 MEAN (ABSOLUTE DIF.) = 15.3053435
 STANDARD DEVIATION = 18.7376333
 90% CONFIDENCE LIMITS -39.0956714 TO 22.5511421
 TOTAL OCCURRENCES = 393

CARRIER: BLUE DIRECTION: Eastbound REGION: North Atlantic



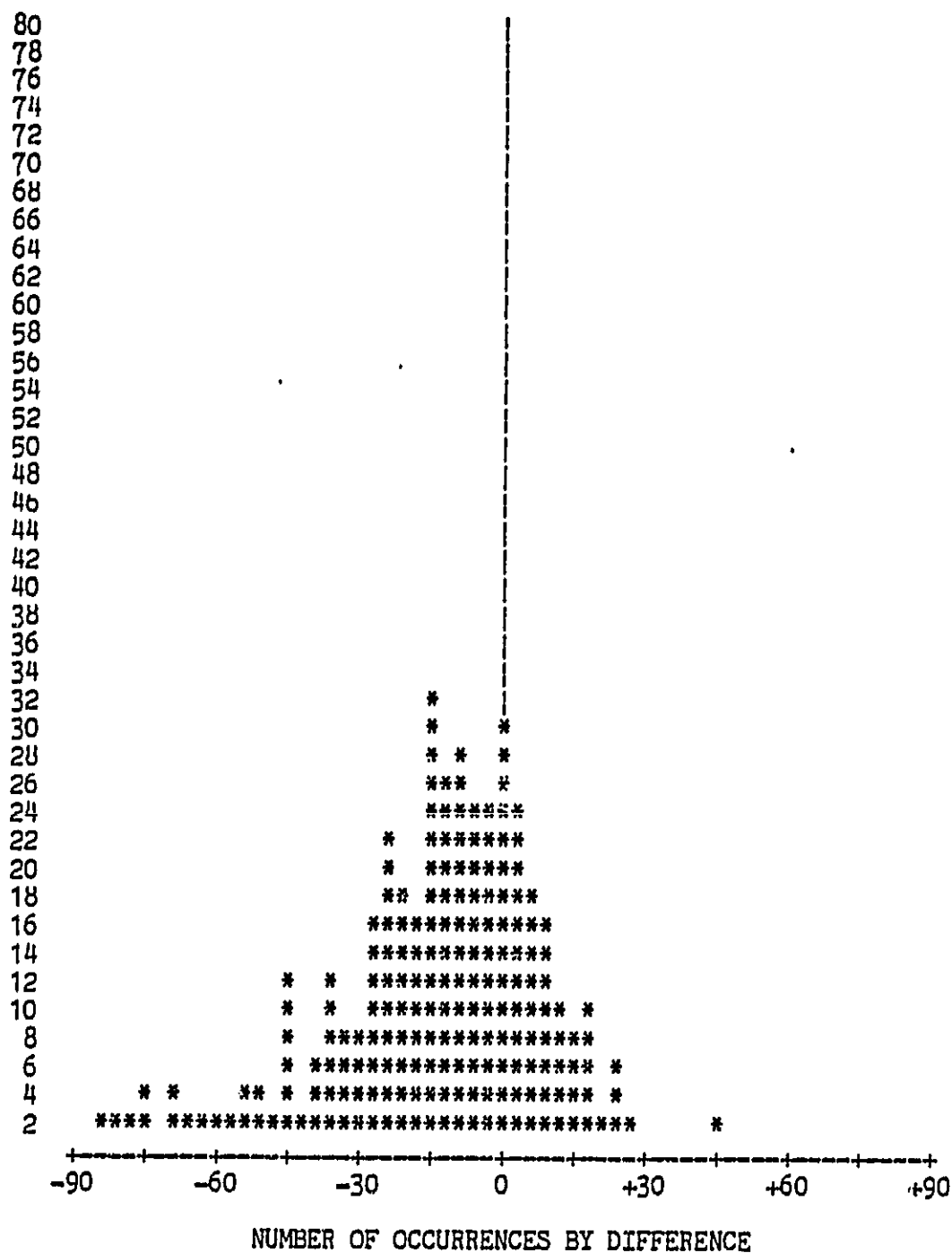
NUMBER OF OCCURRENCES BY DIFFERENCE

Cross-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -4.39694656
 VARIANCE = 478.081619
 MEAN (ABSOLUTE DIF.) = 15.8676845
 STANDARD DEVIATION = 21.8650776
 90% CONFIDENCE LIMITS -40.3649993 TO 31.5711062
 TOTAL OCCURRENCES = 393

CARRIER: BLUE DIRECTION: Eastbound REGION: North Atlantic

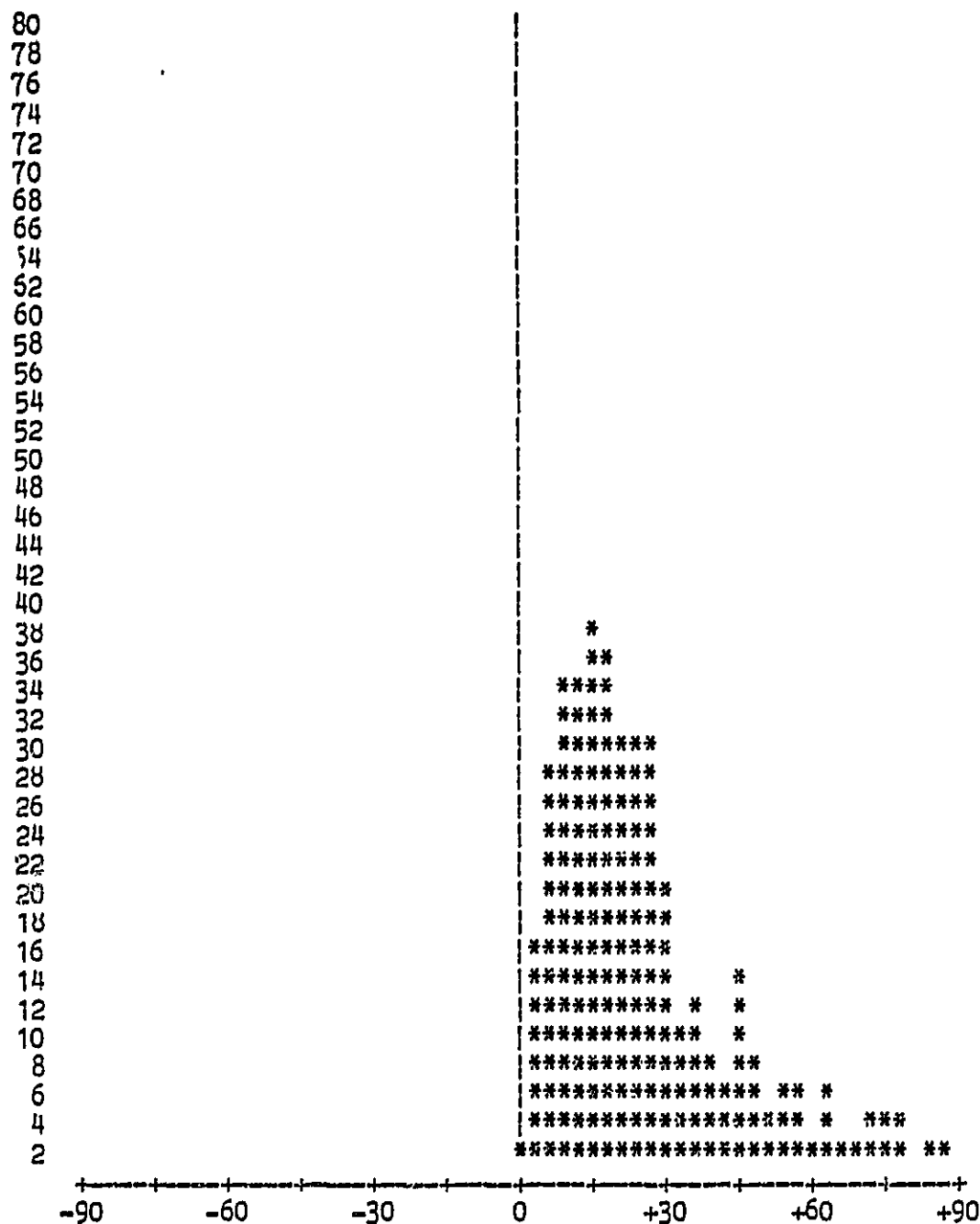


Parallel-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -13.6259542
 VARIANCE = 469.460599
 MEAN (ABSOLUTE DIF.) = 18.4249364
 STANDARD DEVIATION = 21.6670395
 90% CONFIDENCE LIMITS -49.2682341 TO 22.0163258
 TOTAL OCCURRENCES = 393

CARRIER: BLUE DIRECTION: Eastbound REGION: North Atlantic



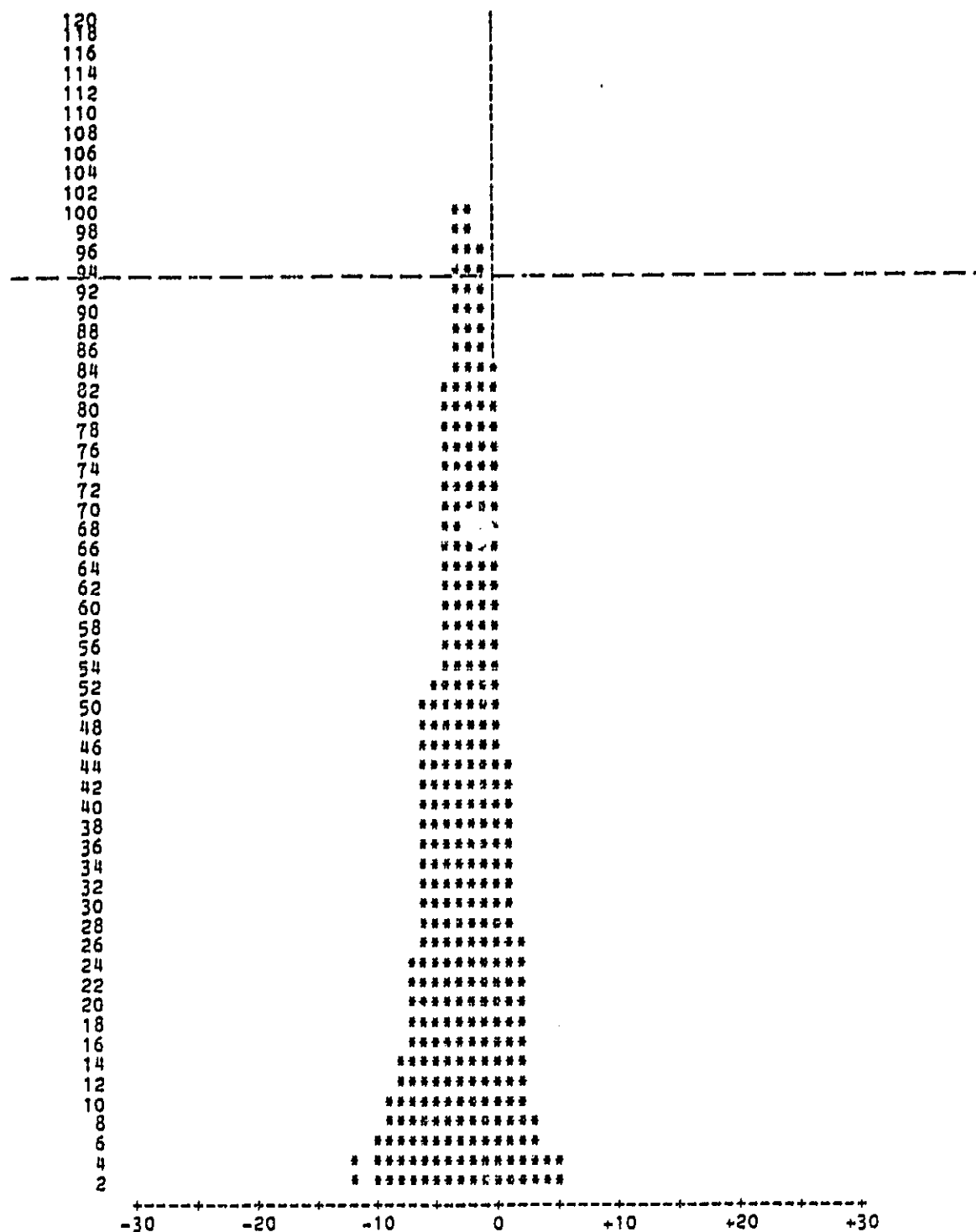
NUMBER OF OCCURRENCES BY DIFFERENCE

Magnitude of Vector Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = 26.2213741
 VARIANCE = 445.902648
 MEAN (ABSOLUTE DIF.) = 26.2213741
 STANDARD DEVIATION = 21.1164071
 90% CONFIDENCE LIMITS -8.51511563 TO 60.9578637
 TOTAL OCCURRENCES = 393

CARRIER: BLUE DIRECTION: Eastbound REGION: North Atlantic

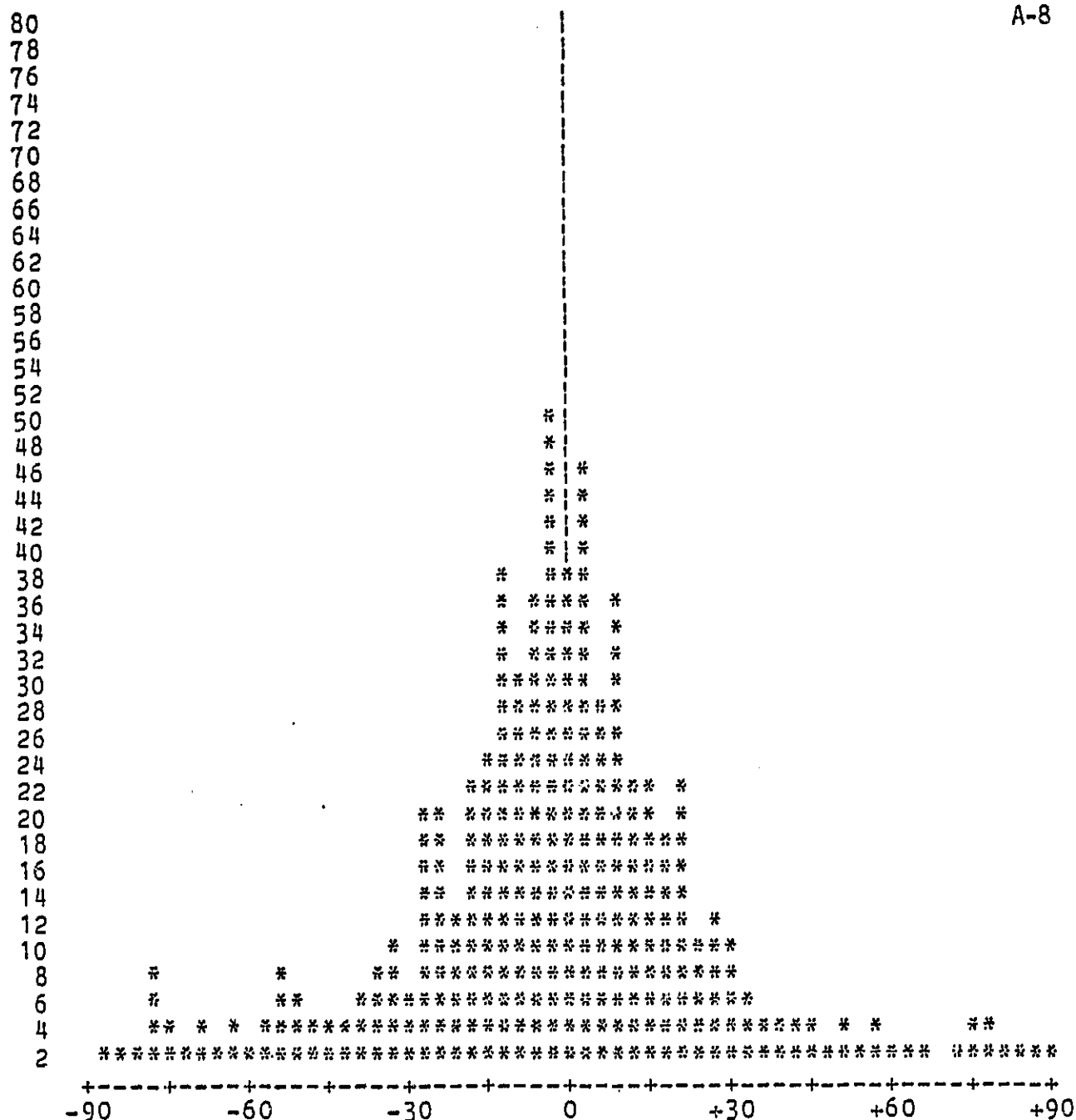


NUMBER OF OCCURRENCES BY DIFFERENCE

Temperature Difference In Degress Centigrade

Operational Segments MINUS AIDS Derived Segments

MEAN	=	-2.53448276	
VARIANCE	=	7.70283393	
MEAN (ABSOLUTE DIF.)	=	2.96551724	
STANDARD DEVIATION	=	2.77539798	
90% CONFIDENCE LIMITS		-7.10001243	TO 2.03104692
TOTAL OCCURRENCES	=	696	SPEAS



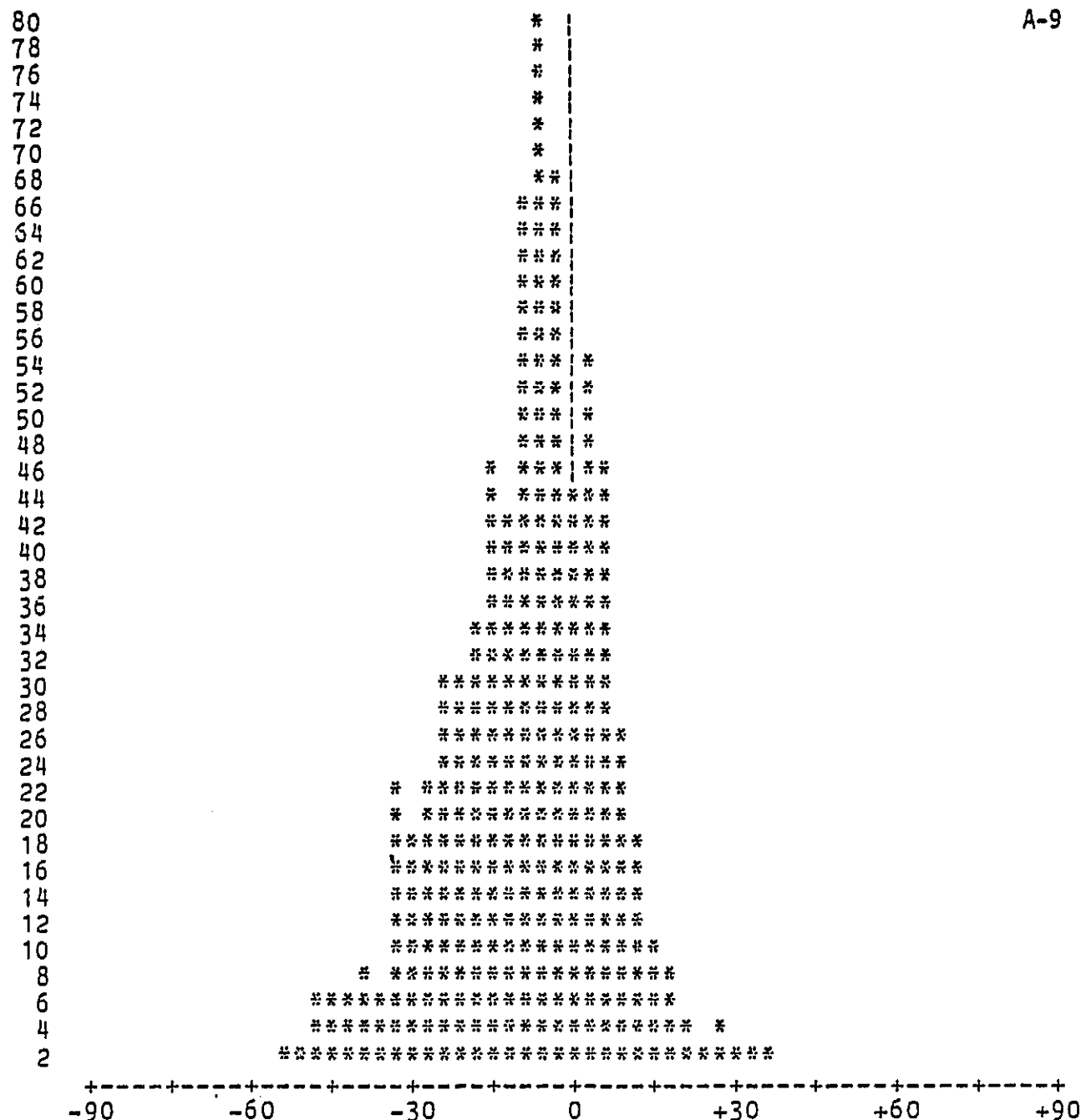
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Direction Difference in Degrees

Operational Segments MINUS AIDS Derived Segments

MEAN = -4.16522989
 VARIANCE = 2226.48276
 MEAN (ABSOLUTE DIF.) = 29.8146552
 STANDARD DEVIATION = 47.1856202
 90% CONFIDENCE LIMITS -81.7855752 TO 73.4551154
 TOTAL OCCURRENCES = 696

CARRIER: BLUE DIRECTION: Westbound REGION: North Atlantic



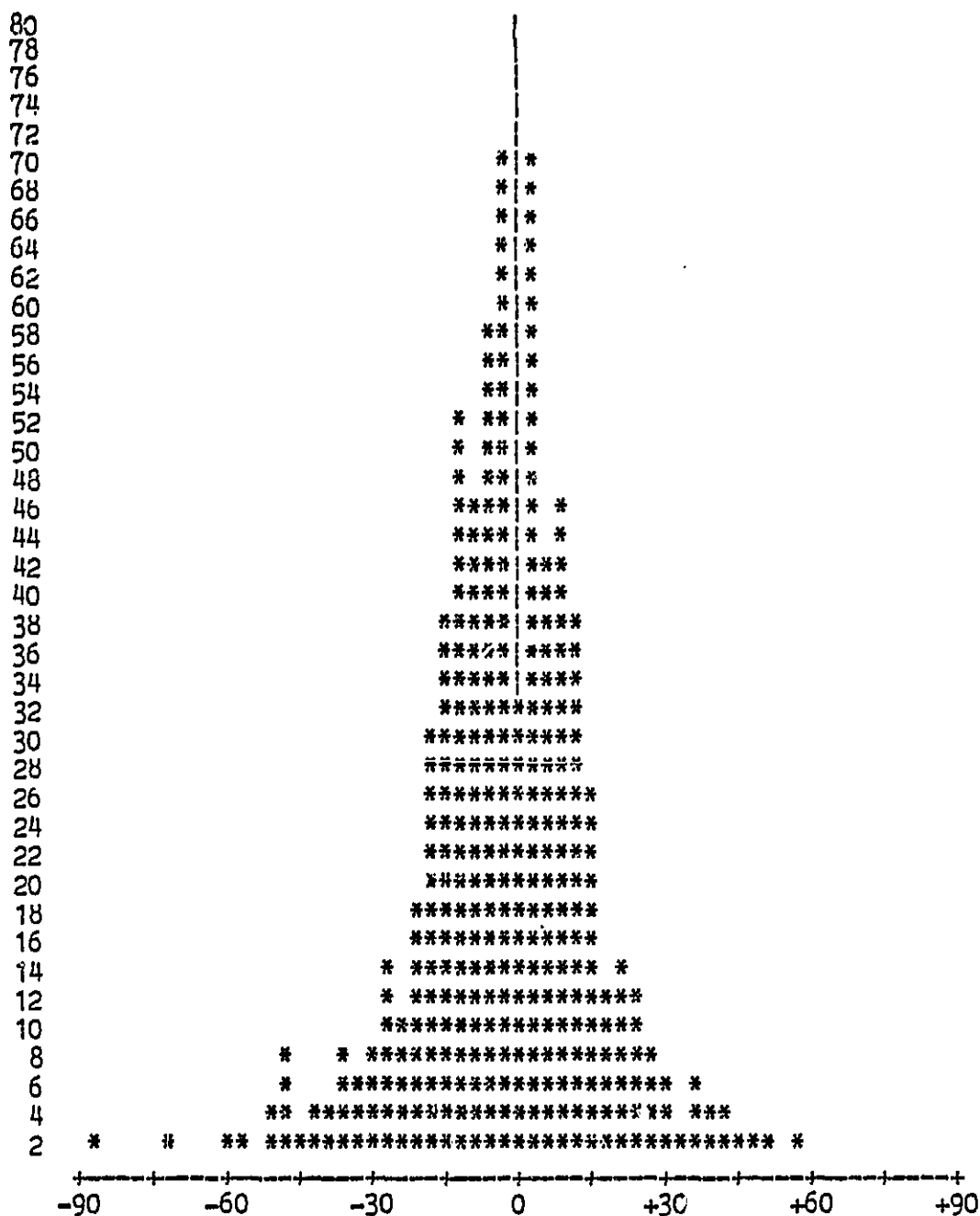
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Speed Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -8.96839081
 VARIANCE = 211.024863
 MEAN (ABSOLUTE DIF.) = 12.9827586
 STANDARD DEVIATION = 14.5266948
 90% CONFIDENCE LIMITS -32.8648039 TO 14.9280222
 TOTAL OCCURRENCES = 696

CARRIER: BLUE DIRECTION: Westbound REGION: North Atlantic



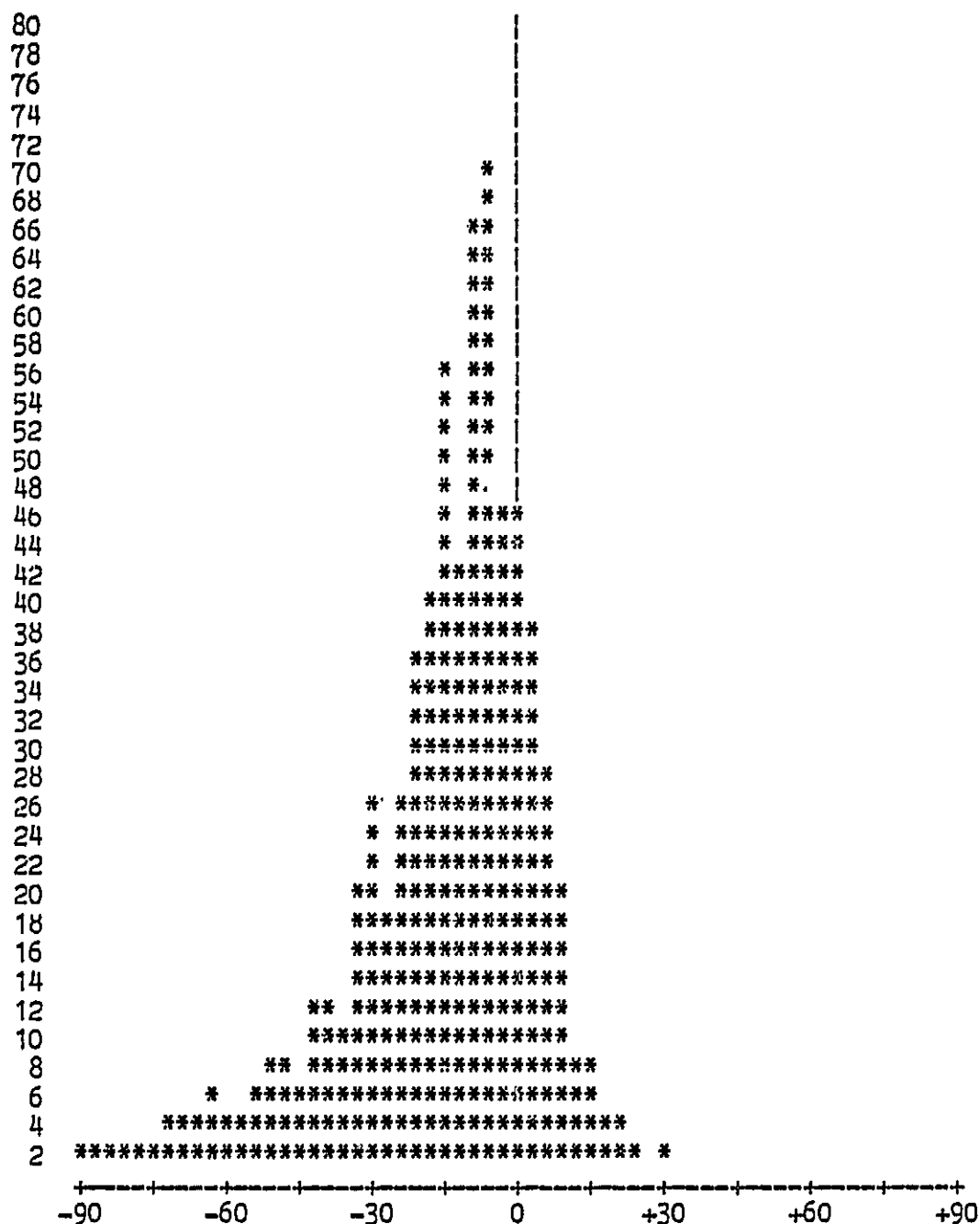
NUMBER OF OCCURRENCES BY DIFFERENCE

Cross-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -2.97844828
 VARIANCE = 307.702122
 MEAN (ABSOLUTE DIF.) = 13.2284483
 STANDARD DEVIATION = 17.5414401
 90% CONFIDENCE LIMITS -31.8341173 TO 25.8772208
 TOTAL OCCURRENCES = 696

CARRIER: BLUE DIRECTION: Westbound REGION: North Atlantic



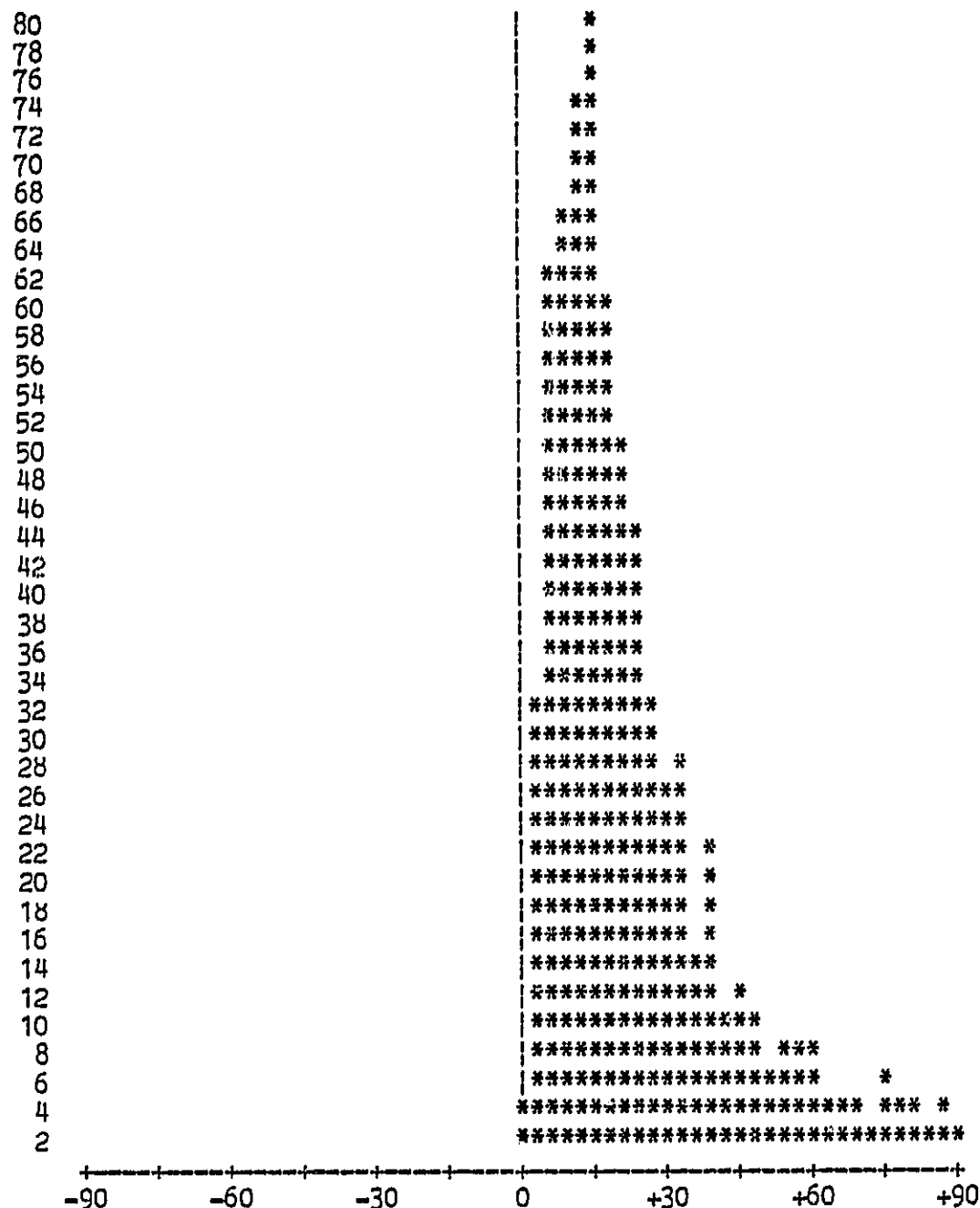
NUMBER OF OCCURRENCES BY DIFFERENCE

Parallel-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -16.9568965
 VARIANCE = 552.150441
 MEAN (ABSOLUTE DIF.) = 19.4051724
 STANDARD DEVIATION = 23.4978816
 90% CONFIDENCE LIMITS -55.6109119 TO 21.6971188
 TOTAL OCCURRENCES = 696

CARRIER: BLUE DIRECTION: Westbound REGION: North Atlantic



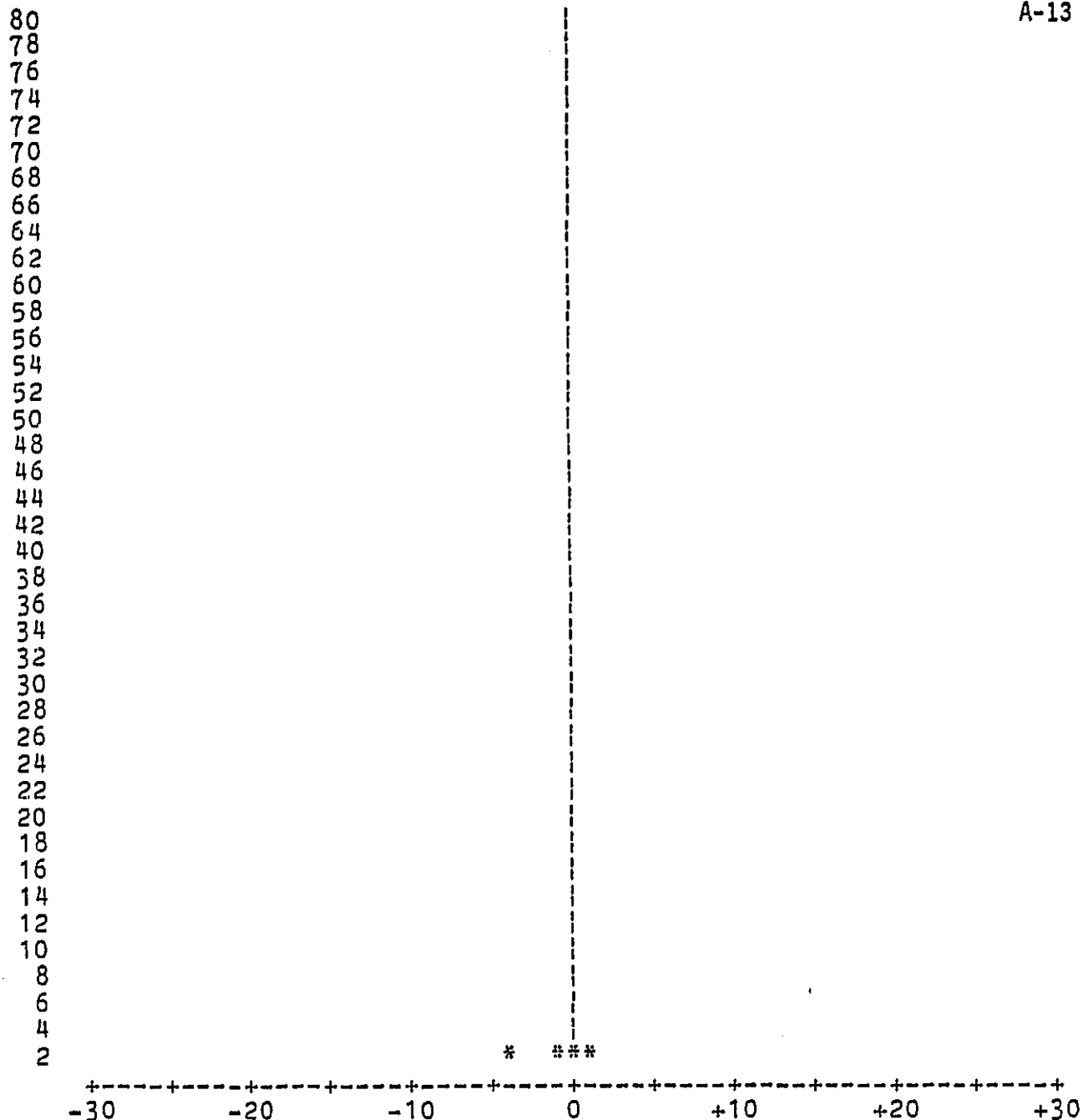
NUMBER OF OCCURRENCES BY DIFFERENCE

Magnitude of Vector Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = 24.908046
 VARIANCE = 509.086373
 MEAN (ABSOLUTE DIF.) = 24.908046
 STANDARD DEVIATION = 22.5629425
 90% CONFIDENCE LIMITS = -12.2079944 TO 62.0240863
 TOTAL OCCURRENCES = 696

CARRIER: BLUE DIRECTION: Westbound REGION: North Atlantic



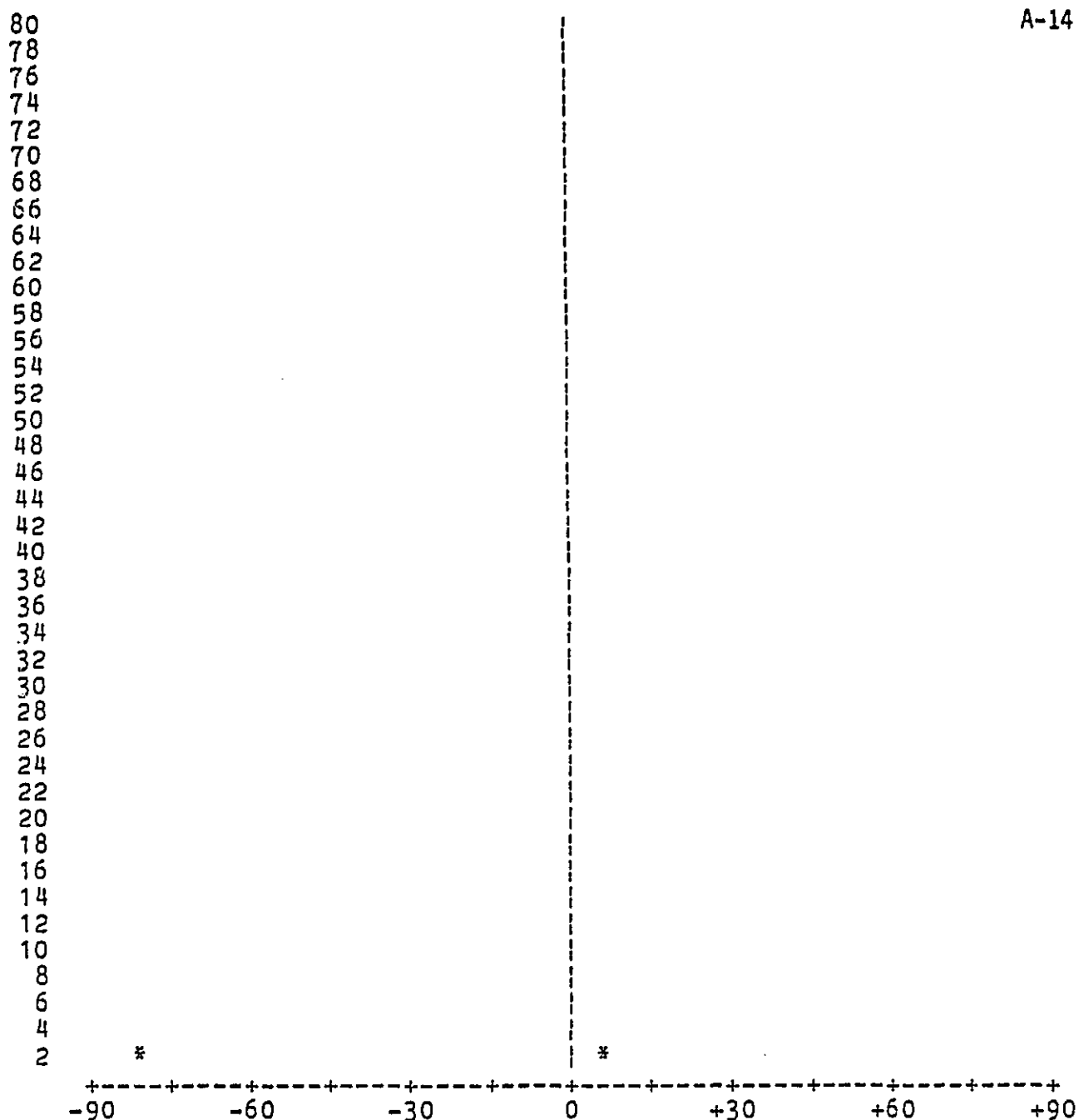
NUMBER OF OCCURRENCES BY DIFFERENCE

Temperature Difference in Degress Centigrade

Operational Segments MINUS AIDS Derived Segments

MEAN = -1
 VARIANCE = 3.5
 MEAN (ABSOLUTE DIF.) = 1.5
 STANDARD DEVIATION = 1.87082869
 90% CONFIDENCE LIMITS = -4.0775132 TO 2.0775132
 TOTAL OCCURRENCES = 4

CARRIER: BLUE DIRECTION: Eastbound REGION: Polar



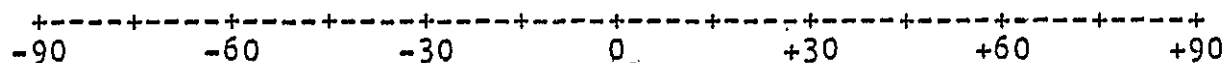
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Direction Difference in Degrees

Operational Segments MINUS AIDS Derived Segments

MEAN = 69
 VARIANCE = 12245.5
 MEAN (ABSOLUTE DIF.) = 109
 STANDARD DEVIATION = 110.659387
 90% CONFIDENCE LIMITS -113.034692 TO 251.034692
 TOTAL OCCURRENCES = 4

CARRIER: BLUE DIRECTION: Eastbound REGION: Polar



Wind Speed Difference in Knots

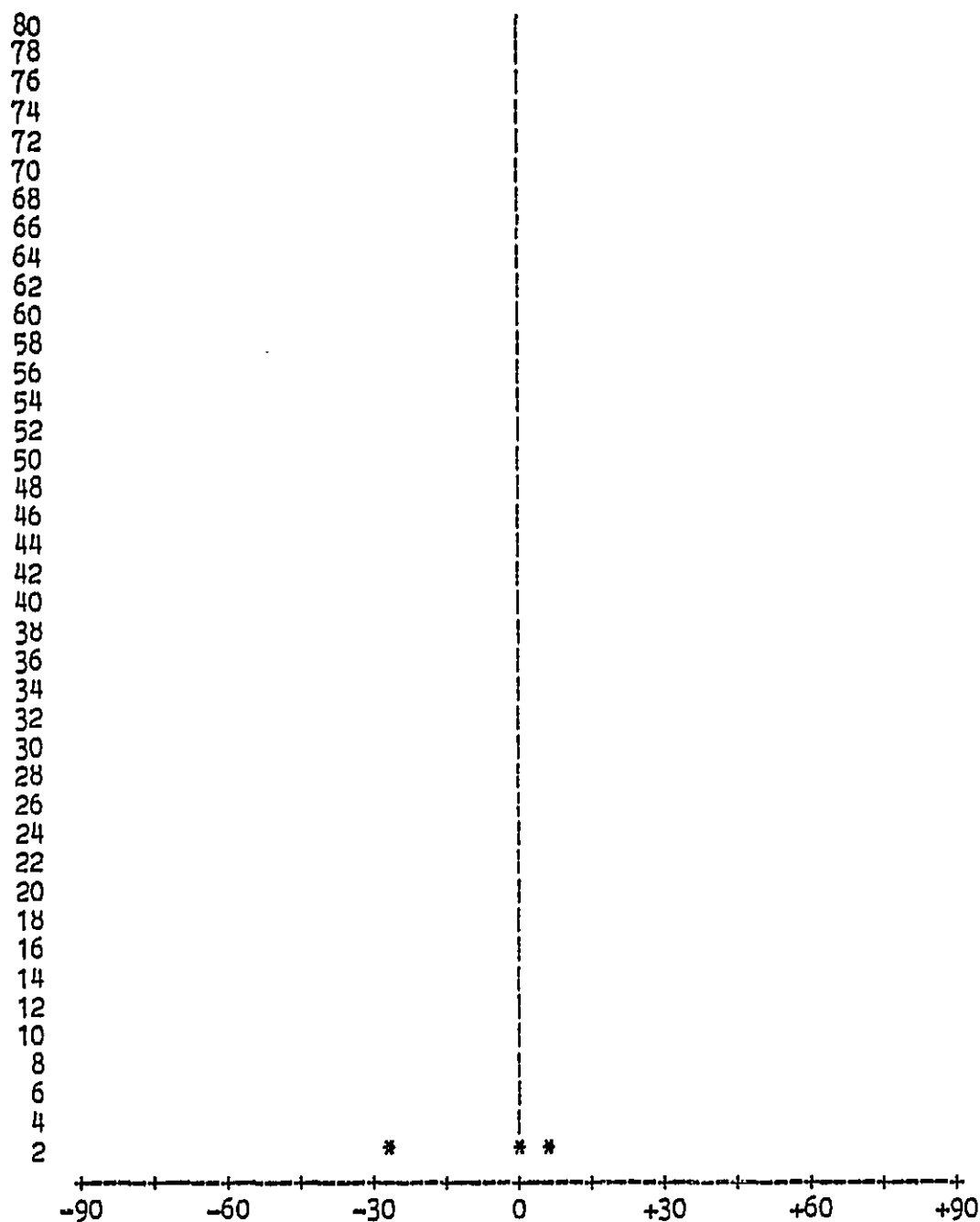
Operational Segments MINUS AIDS Derived Segments

```

MEAN                = -18
VARIANCE            = 256.5
MEAN (ABSOLUTE DIF.)= 19.5
STANDARD DEVIATION  = 16.0156174
90% CONFIDENCE LIMITS      -44.3456906   TO   8.34569062
TOTAL OCCURRENCES    = 4

```

CARRIER: BLUE DIRECTION: Eastbound REGION: Polar



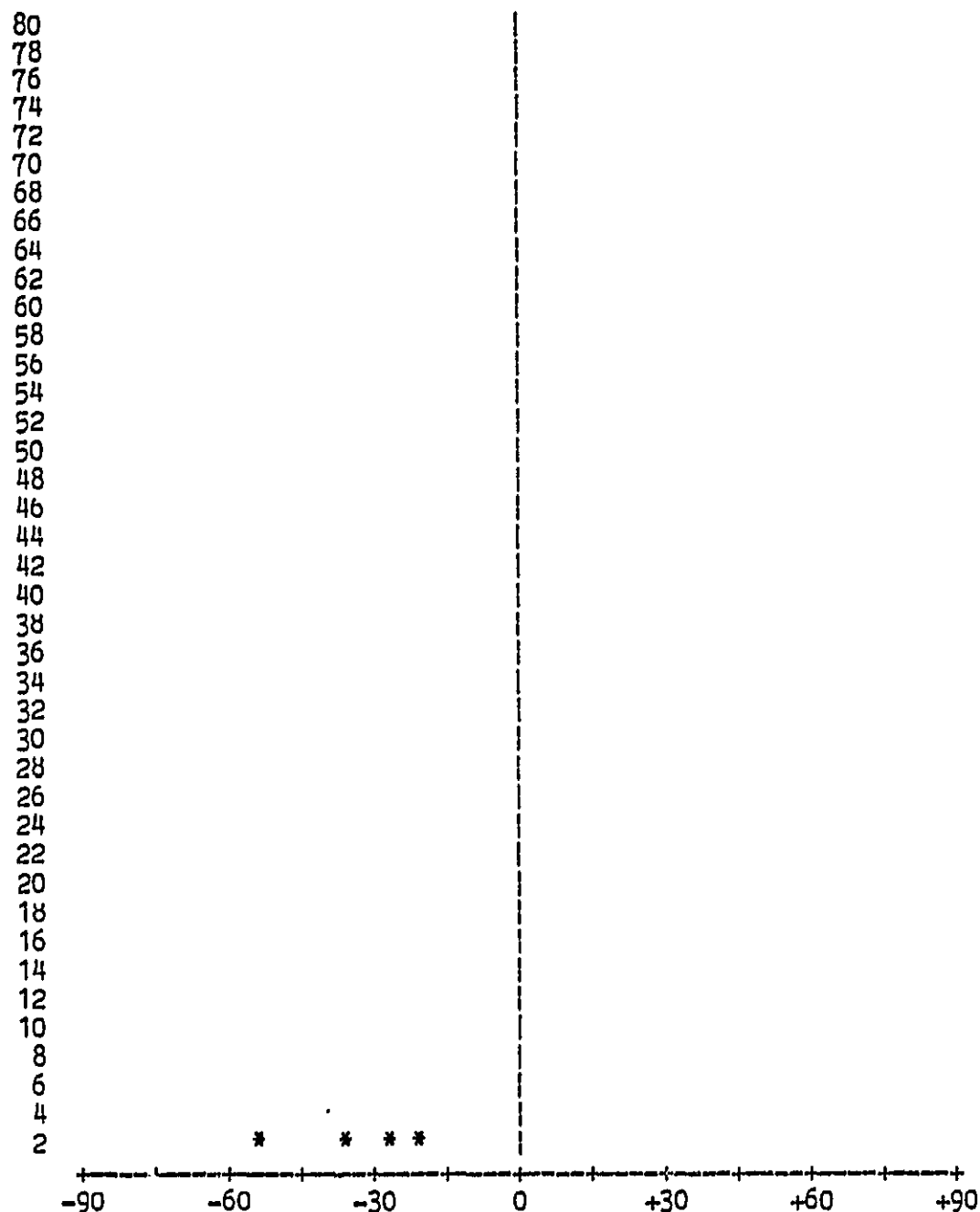
NUMBER OF OCCURRENCES BY DIFFERENCE

Cross-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -5
 VARIANCE = 164
 MEAN (ABSOLUTE DIF.) = 8.5
 STANDARD DEVIATION = 12.8062485
 90% CONFIDENCE LIMITS = -26.0662788 TO 16.0662788
 TOTAL OCCURRENCES = 4

CARRIER: BLUE DIRECTION: Eastbound REGION: Polar



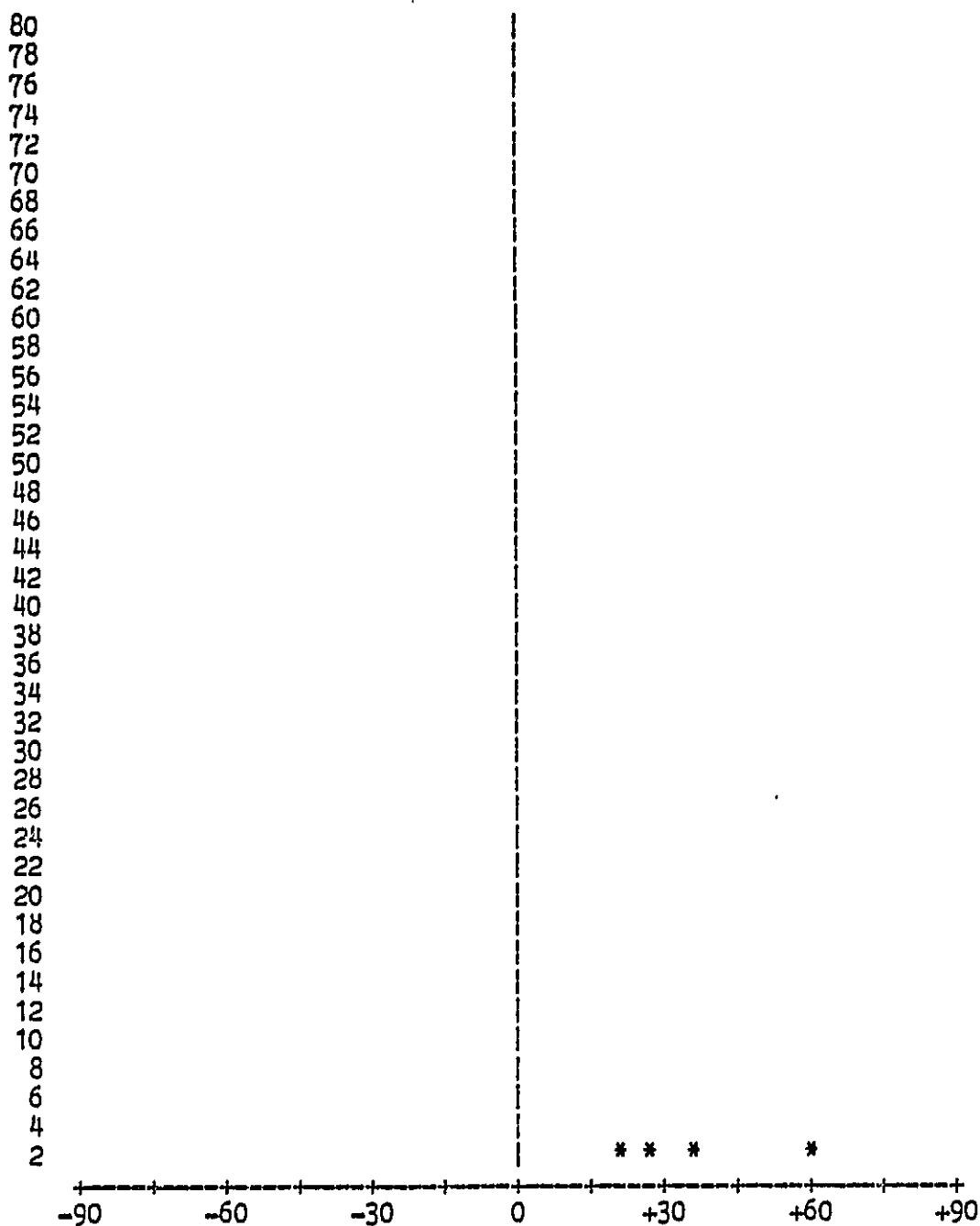
NUMBER OF OCCURRENCES BY DIFFERENCE

Parallel-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -34.25
 VARIANCE = 138.6875
 MEAN (ABSOLUTE DIF.) = 34.25
 STANDARD DEVIATION = 11.7765657
 90% CONFIDENCE LIMITS -53.6224506 TO -14.8775494
 TOTAL OCCURRENCES = 4

CARRIER: BLUE DIRECTION: Eastbound REGION: Polar



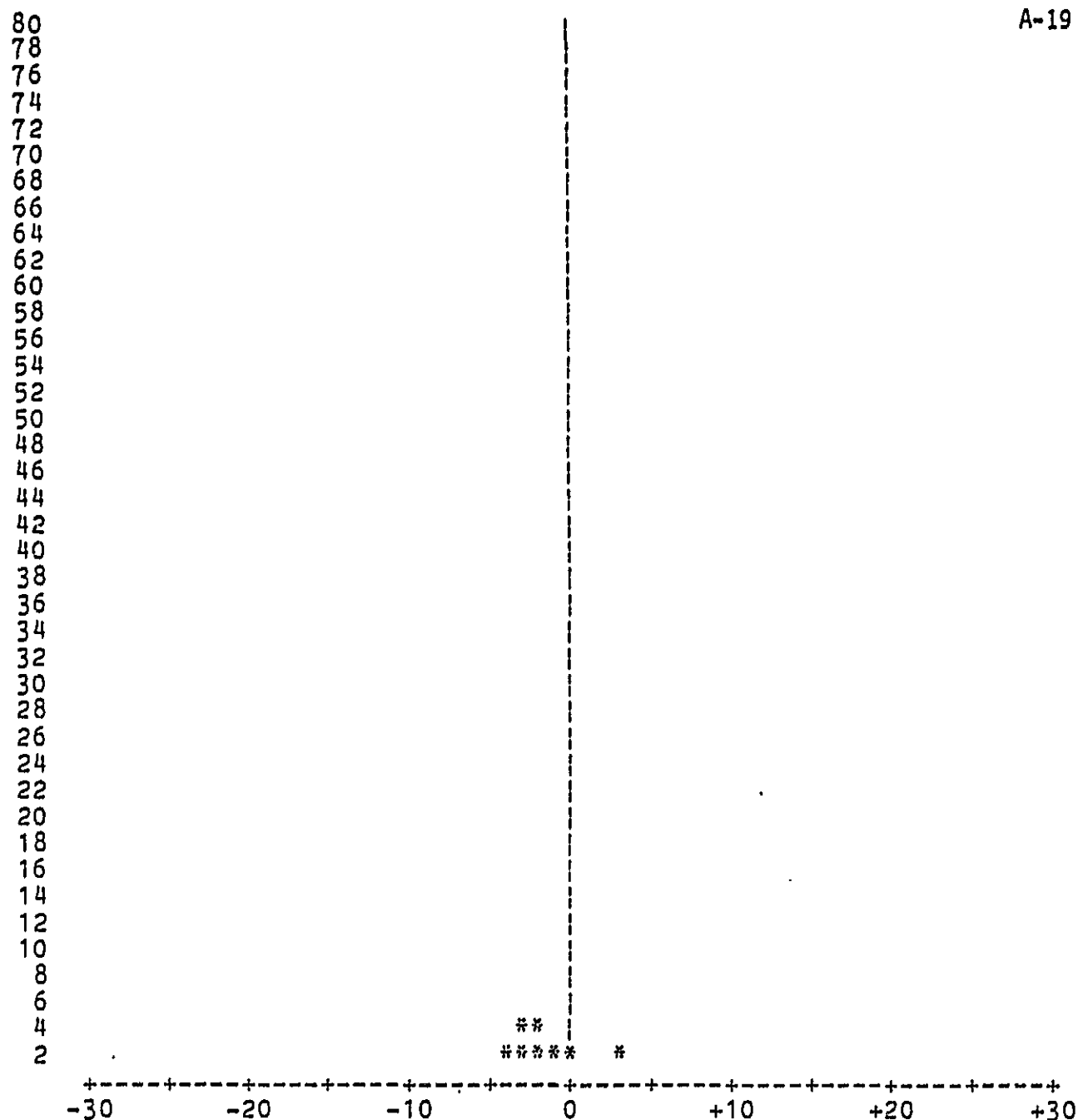
NUMBER OF OCCURRENCES BY DIFFERENCE

Magnitude of Vector Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN	=	35.5	
VARIANCE	=	213.25	
MEAN (ABSOLUTE DIF.)	=	35.5	
STANDARD DEVIATION	=	14.6030819	
90% CONFIDENCE LIMITS		11.4779303	TO 59.5220697
TOTAL OCCURRENCES	=	4	

CARRIER: BLUE DIRECTION: Eastbound REGION: Polar



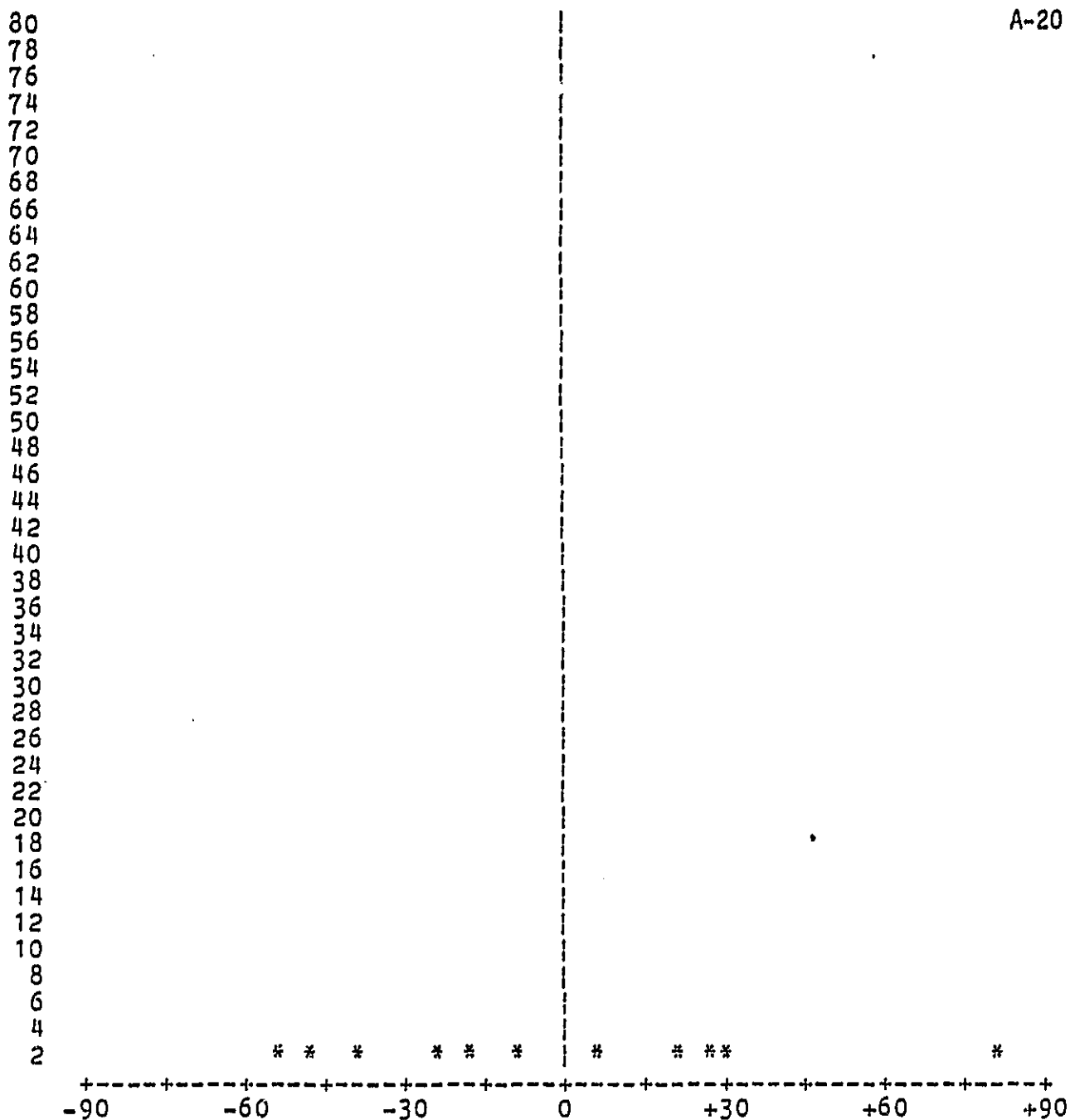
NUMBER OF OCCURRENCES BY DIFFERENCE

Temperature Difference in Degress Centigrade

Operational Segments MINUS AIDS Derived Segments

MEAN = -1.69230769
 VARIANCE = 3.13609468
 MEAN (ABSOLUTE DIF.) = 2.15384615
 STANDARD DEVIATION = 1.77090222
 90% CONFIDENCE LIMITS -4.60544185 TO 1.22082646
 TOTAL OCCURRENCES = 13

CARRIER: BLUE DIRECTION: Westbound REGION: Polar



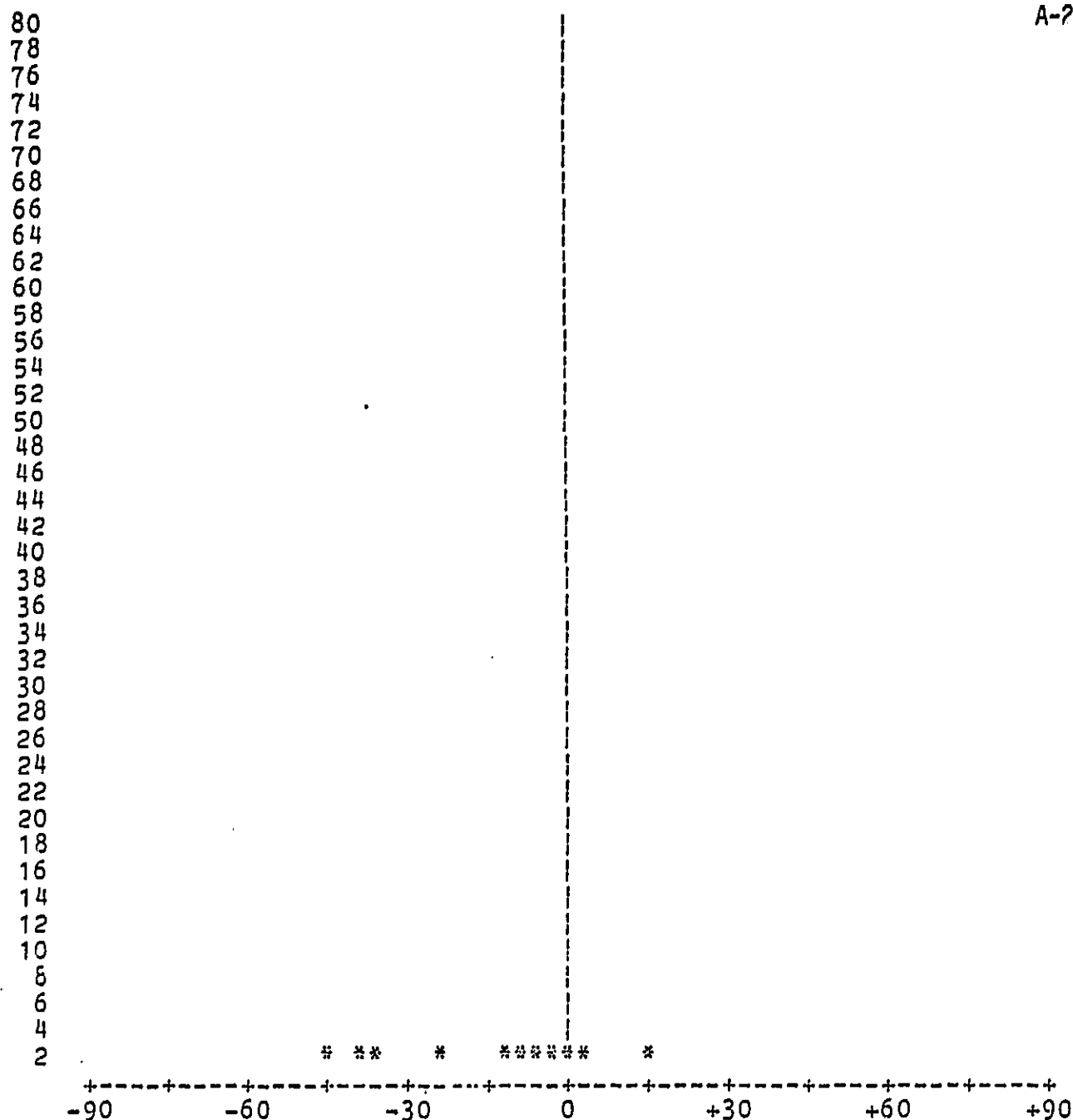
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Direction Difference in Degrees

Operational Segments MINUS AIDS Derived Segments

MEAN	=	-17.9230769	
VARIANCE	=	2589.76332	
MEAN (ABSOLUTE DIF.)	=	43.3076923	
STANDARD DEVIATION	=	50.8897172	
90% CONFIDENCE LIMITS		-101.636662	TO 65.7905079
TOTAL OCCURRENCES	=	13	

CARRIER: BLUE DIRECTION: Westbound REGION: Polar



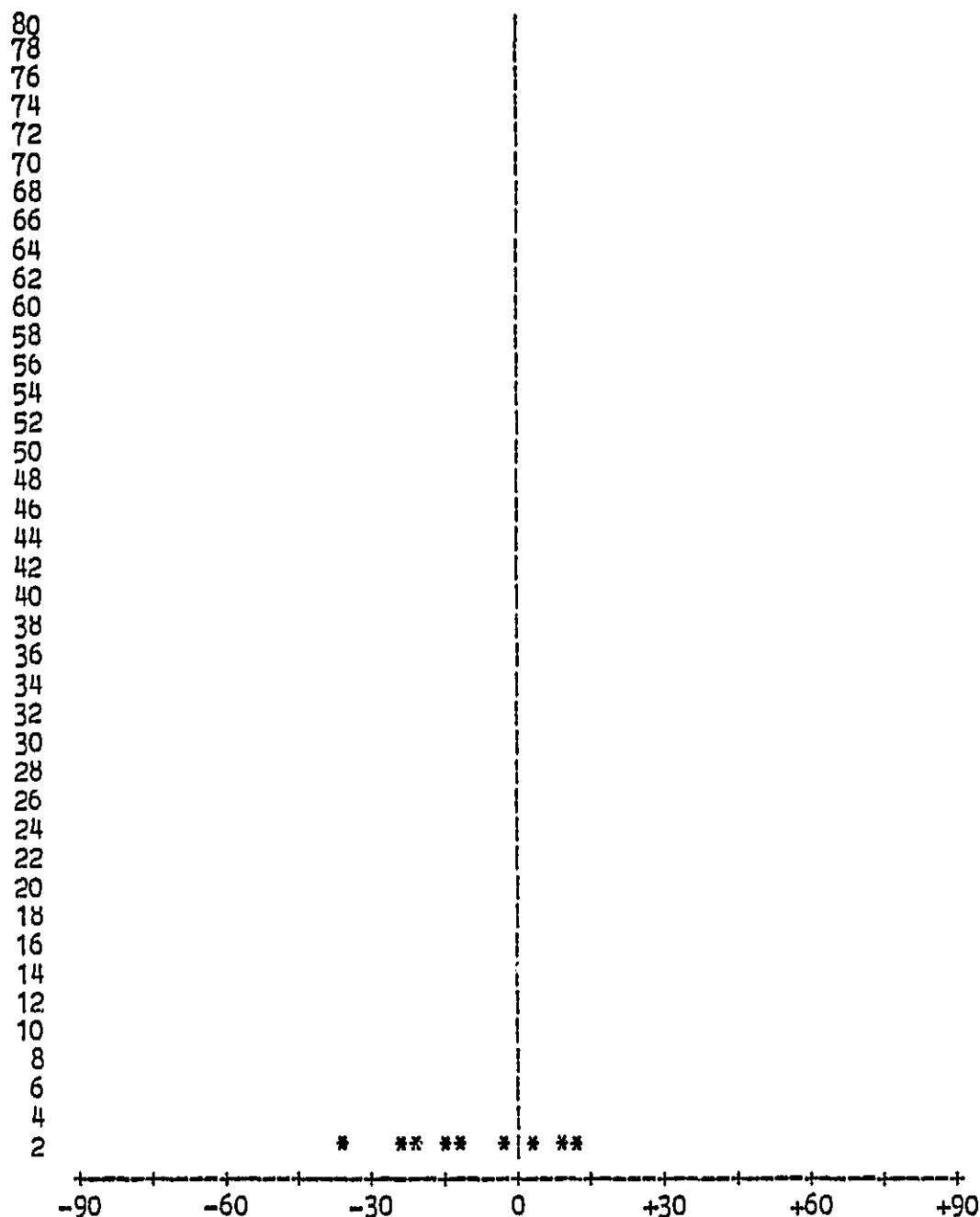
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Speed Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN	=	-11.3846154	
VARIANCE	=	337.159764	
MEAN (ABSOLUTE DIF.)	=	16.3076923	
STANDARD DEVIATION	=	18.3619107	
90% CONFIDENCE LIMITS		-41.5899585	TO 18.8207277
TOTAL OCCURRENCES	=	13	

CARRIER: BLUE DIRECTION: Westbound REGION: Polar



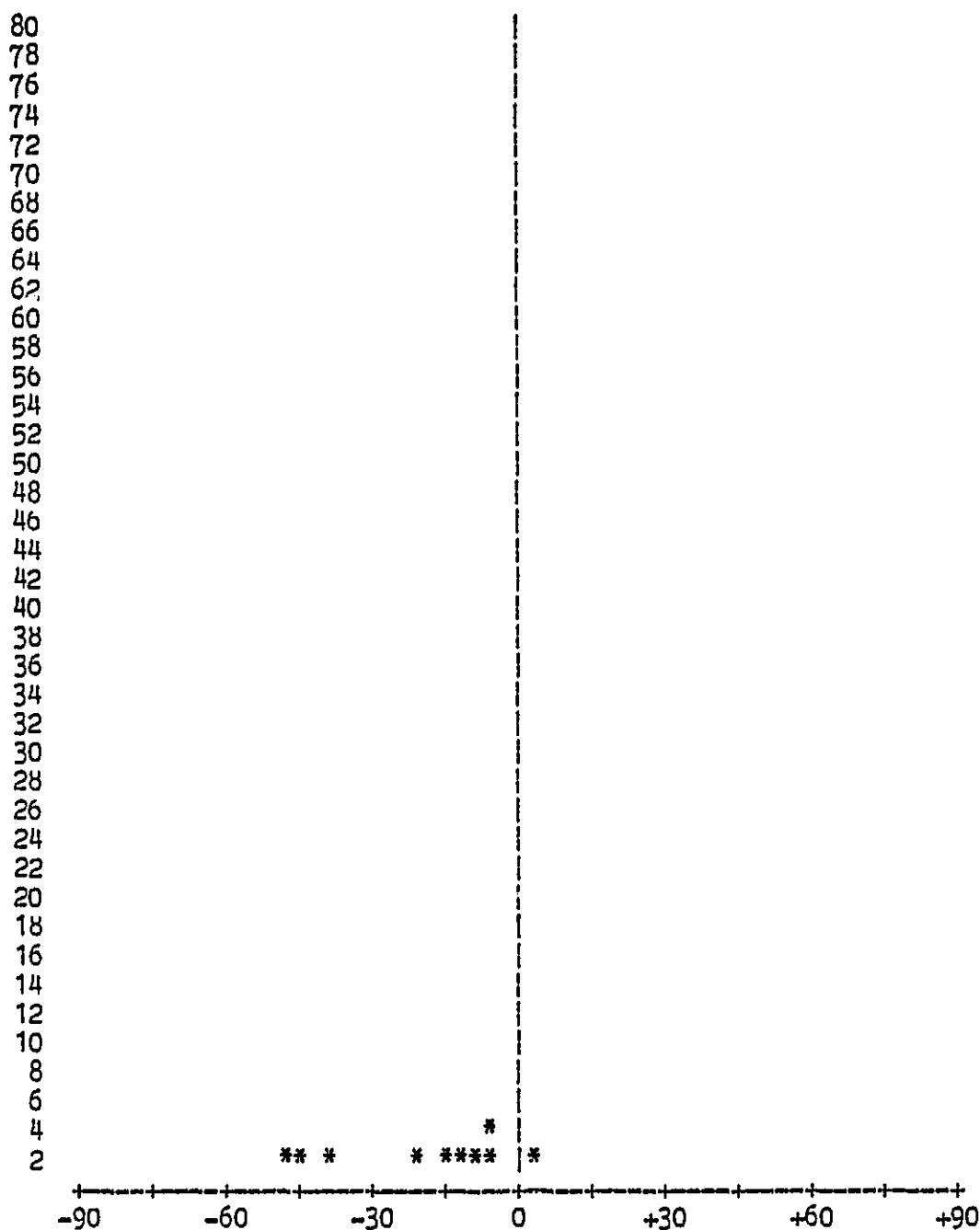
NUMBER OF OCCURRENCES BY DIFFERENCE

Cross-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -8.69230769
 VARIANCE = 250.366864
 MEAN (ABSOLUTE DIF.) = 15.4615385
 STANDARD DEVIATION = 15.8229853
 90% CONFIDENCE LIMITS -34.7211186 TO 17.3365032
 TOTAL OCCURRENCES = 13

CARRIER: BLUE DIRECTION: Westbound REGION: Polar



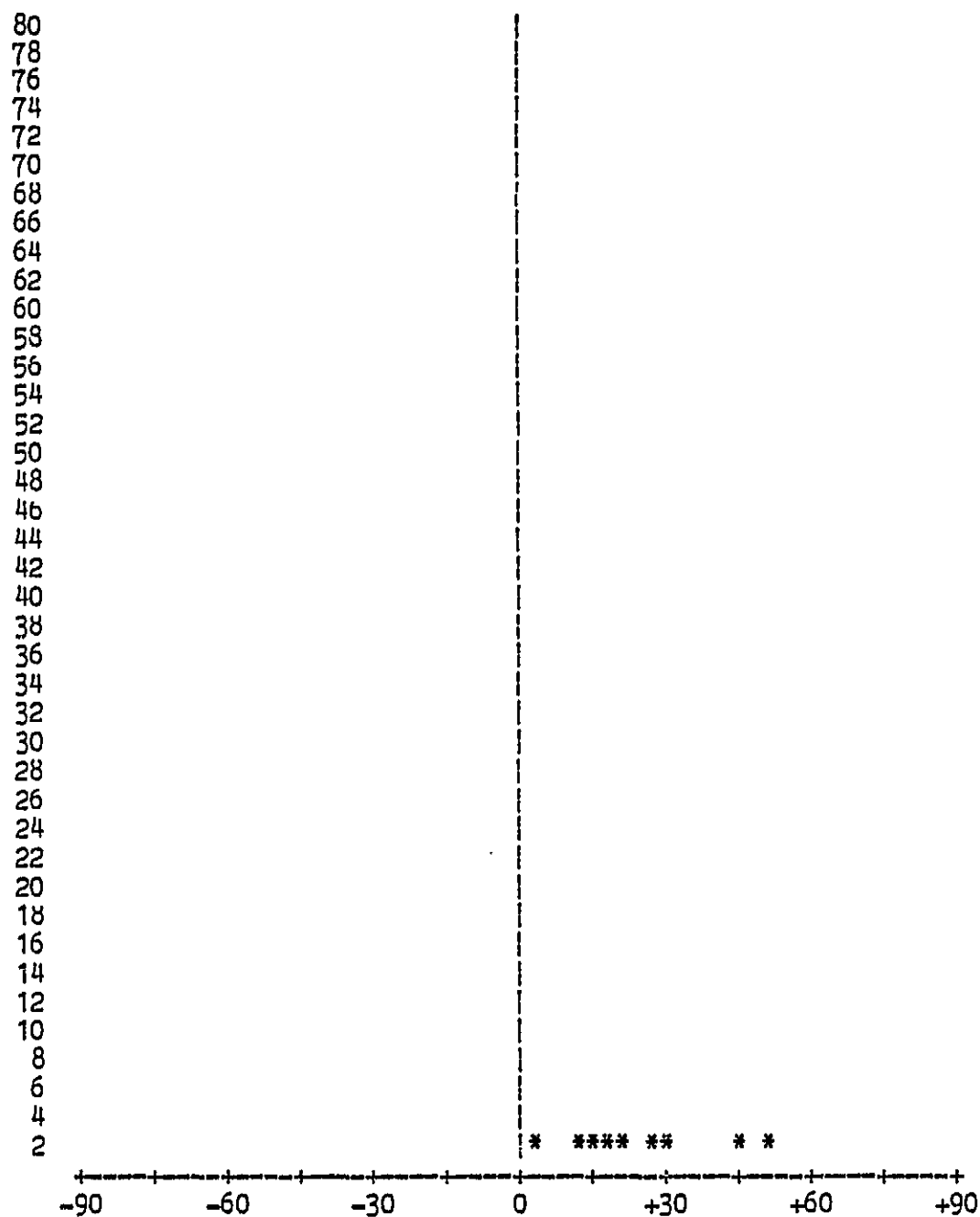
NUMBER OF OCCURRENCES BY DIFFERENCE

Parallel-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -19.769230^a
 VARIANCE = 275.869823
 MEAN (ABSOLUTE DIF.) = 20.0769231
 STANDARD DEVIATION = 16.6093194
 90% CONFIDENCE LIMITS -47.0915777 TO 7.5531161
 TOTAL OCCURRENCES = 13

CARRIER: BLUE DIRECTION: Westbound REGION: Polar



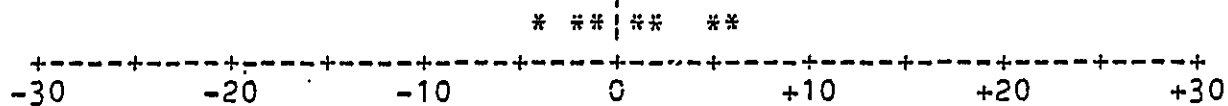
NUMBER OF OCCURRENCES BY DIFFERENCE

Magnitude of Vector Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN	=	26.5384615	
VARIANCE	=	257.171598	
MEAN (ABSOLUTE DIF.)	=	26.5384615	
STANDARD DEVIATION	=	16.0365706	
90% CONFIDENCE LIMITS		.158302828	TO 52.9186203
TOTAL OCCURRENCES	=	13	

CARRIER: BLUE DIRECTION: Westbound REGION: Polar



Temperature Difference in Degress Centigrade

Operational Segments MINUS AIDS Derived Segments

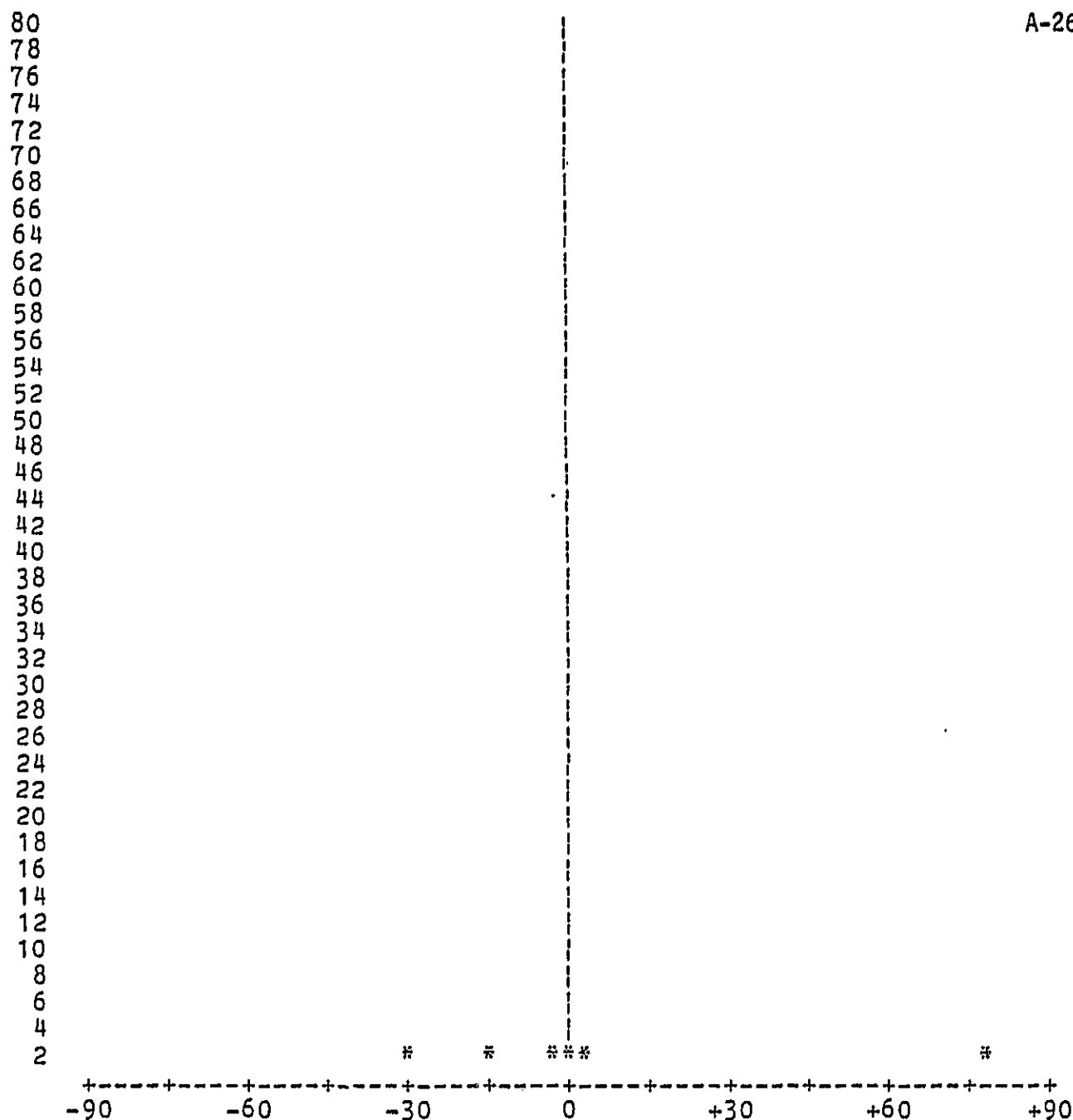
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MEAN                =      .4444444444
VARIANCE            =      10.0246914
MEAN (ABSOLUTE DIF.)=      2.66666667
STANDARD DEVIATION  =      3.1661793
90% CONFIDENCE LIMITS      -4.76392051      TO      5.6528094
TOTAL OCCURRENCES    =      9

```

CARRIER: BLUE DIRECTION: Eastbound REGION: Middle Atlantic

PROC SPEAS



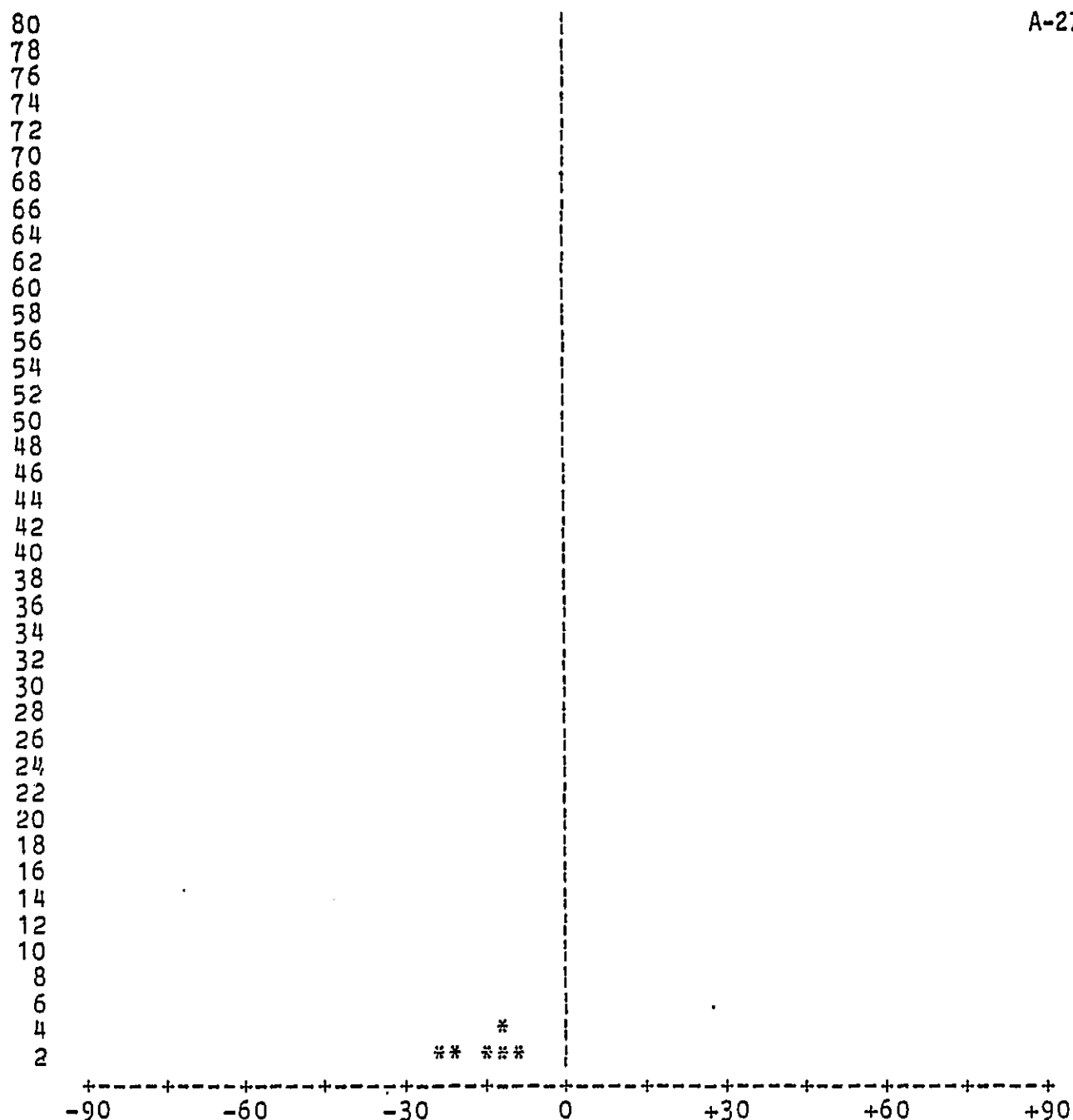
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Direction Difference in Degrees

Operational Segments MINUS AIDS Derived Segments

MEAN = -13
 VARIANCE = 6440.00001
 MEAN (ABSOLUTE DIF.) = 57.8888889
 STANDARD DEVIATION = 80.2496106
 90% CONFIDENCE LIMITS -145.01061 TO 119.01061
 TOTAL OCCURRENCES = 9

CARRIER: BLUE DIRECTION: Eastbound REGION: Middle Atlantic



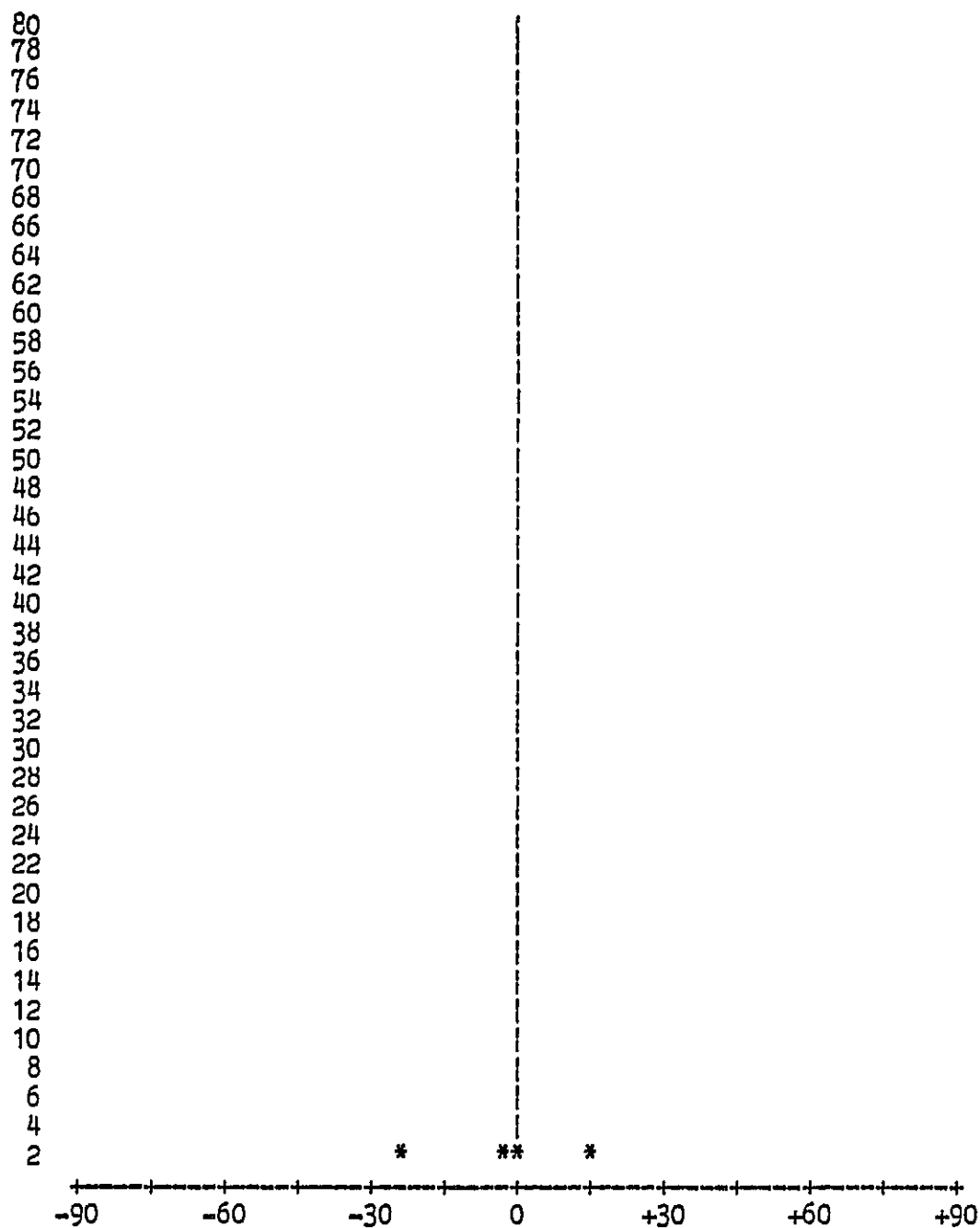
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Speed Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -14.4444444
 VARIANCE = 21.1358025
 MEAN (ABSOLUTE DIF.) = 14.4444444
 STANDARD DEVIATION = 4.59736909
 90% CONFIDENCE LIMITS -22.0071166 TO -6.8817723
 TOTAL OCCURRENCES = 9

CARRIER: BLUE DIRECTION: Eastbound REGION: Middle Atlantic



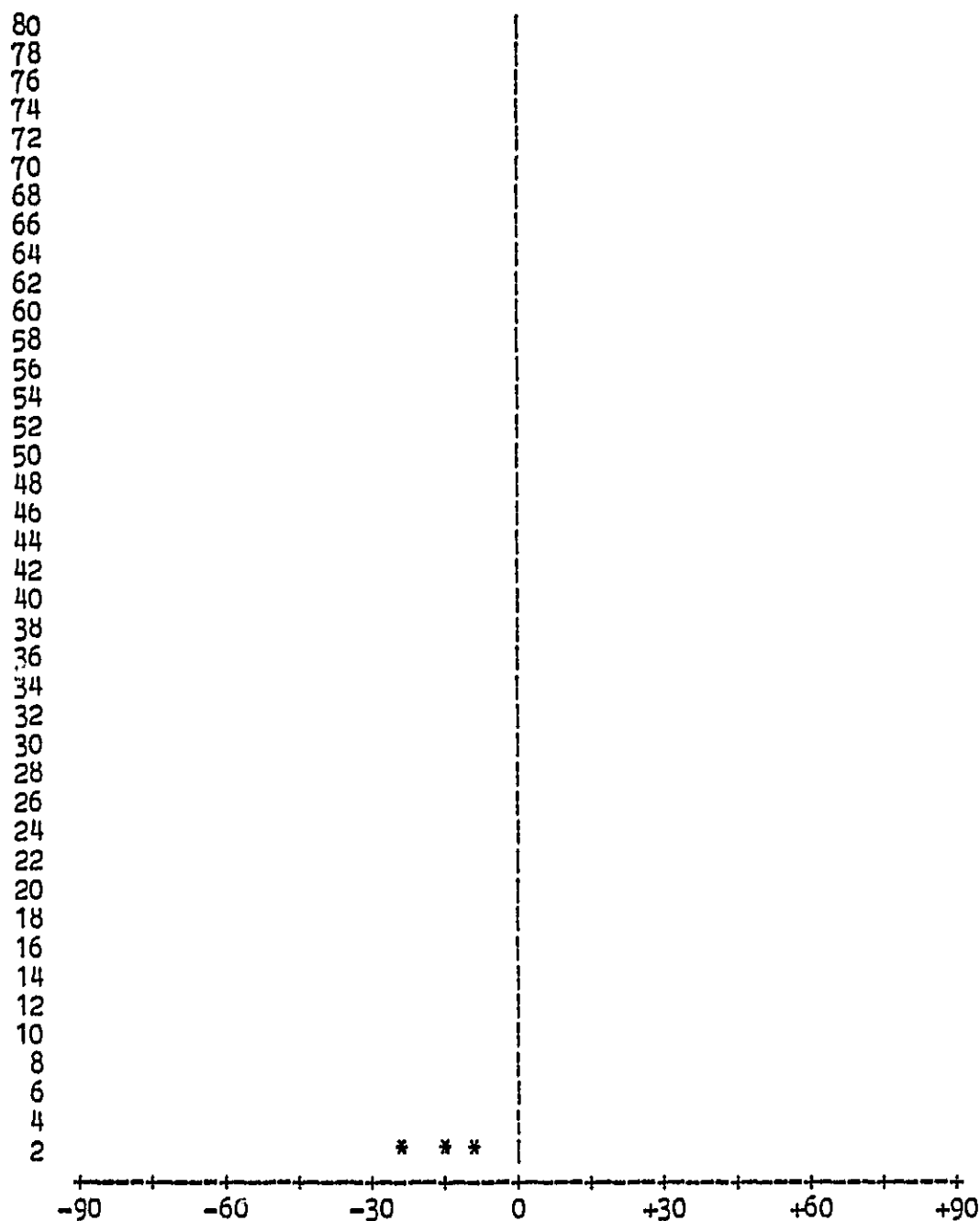
NUMBER OF OCCURRENCES BY DIFFERENCE

Cross-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -2.75
 VARIANCE = 193.6875
 MEAN (ABSOLUTE DIF.) = 10.25
 STANDARD DEVIATION = 13.9171657
 90% CONFIDENCE LIMITS -25.6437375 TO 20.1437375
 TOTAL OCCURRENCES = 4

CARRIER: BLUE DIRECTION: Eastbound REGION: Middle Atlantic



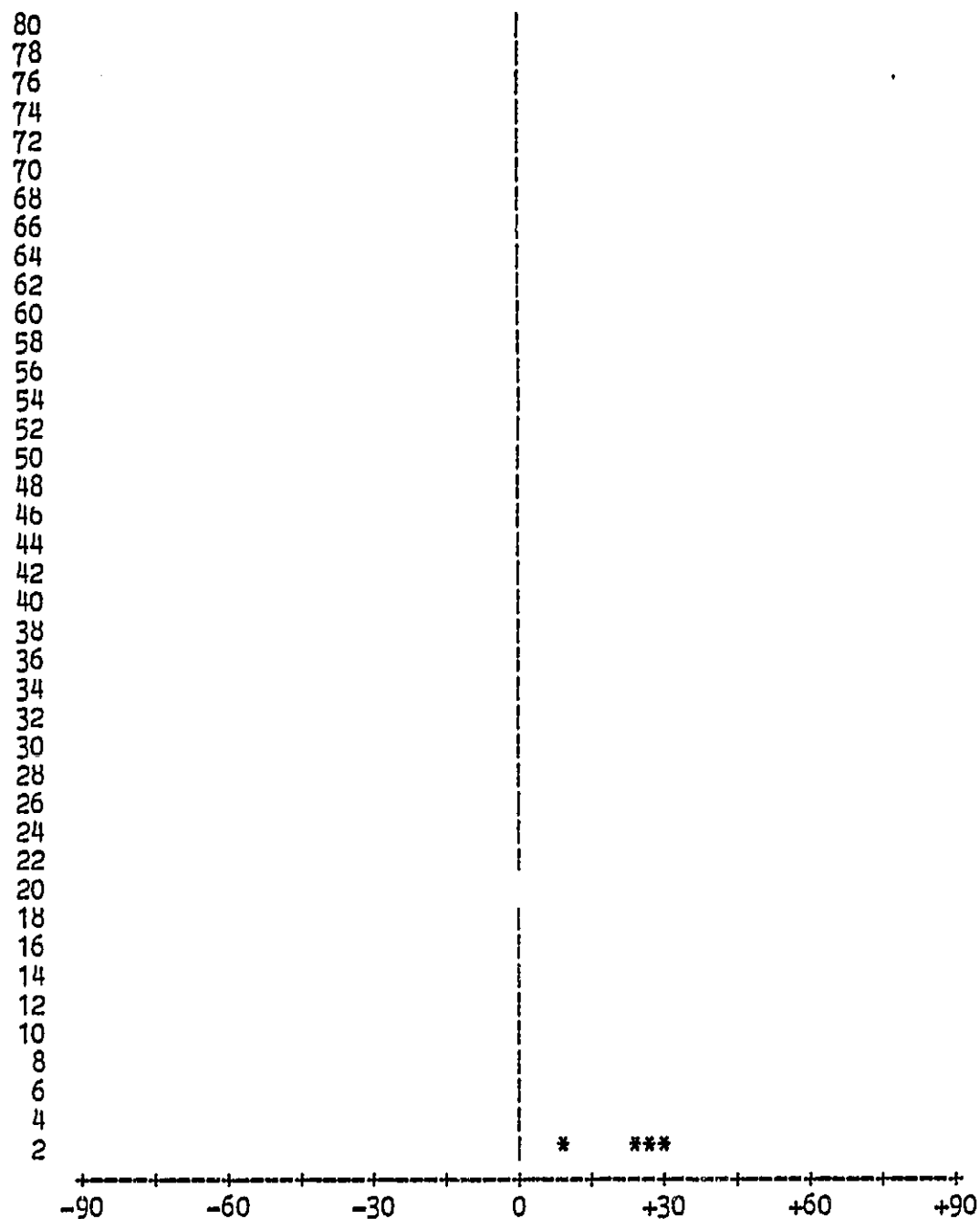
NUMBER OF OCCURRENCES BY DIFFERENCE

Parallel-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -17.75
 VARIANCE = 42.6875
 MEAN (ABSOLUTE DIF.) = 17.75
 STANDARD DEVIATION = 6.53356718
 90% CONFIDENCE LIMITS -28.497718 TO -7.00228199
 TOTAL OCCURRENCES = 4

CARRIER: BLUE DIRECTION: Eastbound REGION: Middle Atlantic



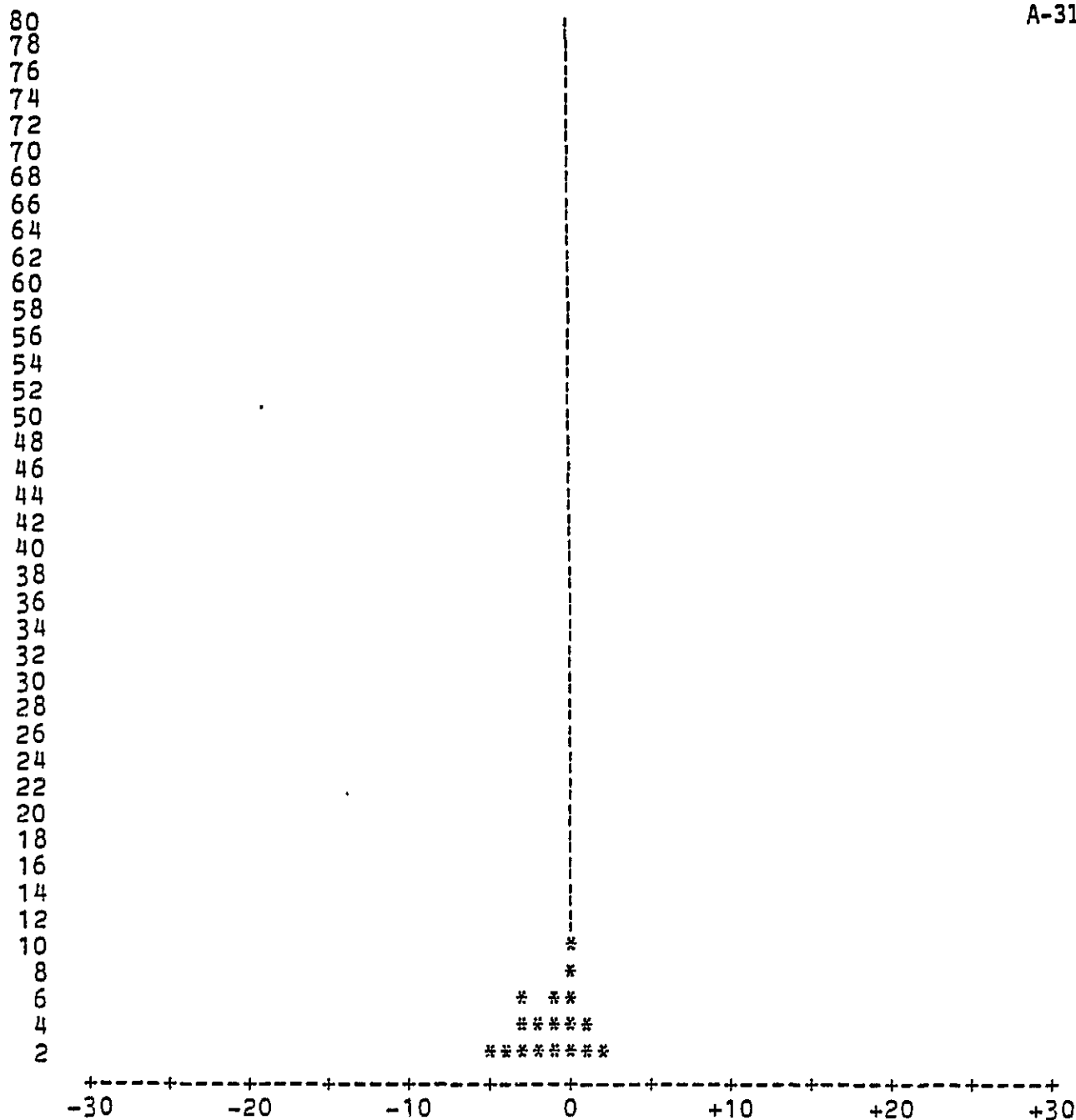
NUMBER OF OCCURRENCES BY DIFFERENCE

Magnitude of Vector Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN	=	22	
VARIANCE	=	61	
MEAN (ABSOLUTE DIF.)	=	22	
STANDARD DEVIATION	=	7.81024968	
90% CONFIDENCE LIMITS		9.15213928	TO 34.8478607
TOTAL OCCURRENCES	=	4	

CARRIER: BLUE DIRECTION: Eastbound REGION: Middle Atlantic

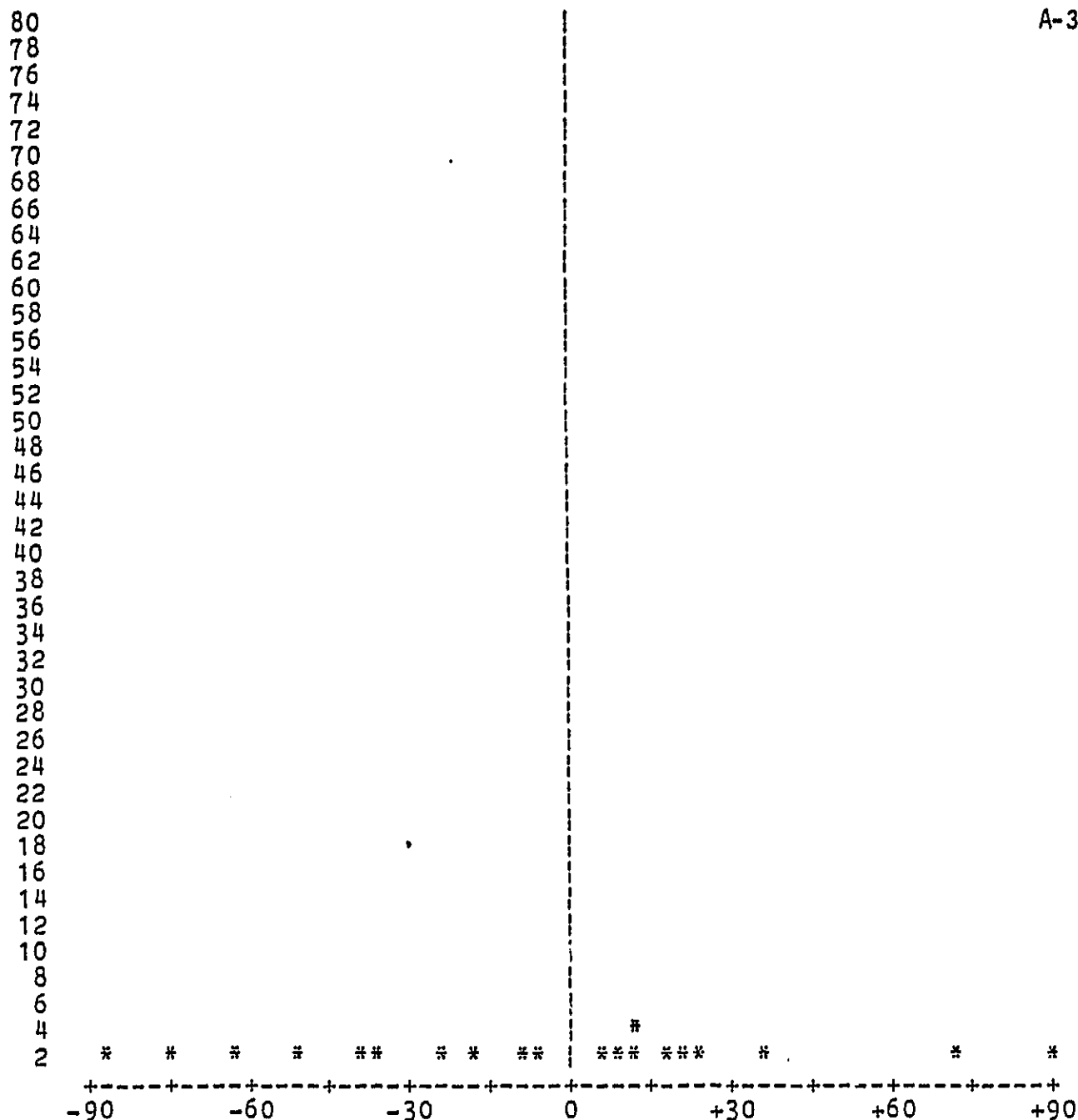


Temperature Difference in Degress Centigrade

Operational Segments MINUS AIDS Derived Segments

MEAN = -1.03125
 VARIANCE = 3.03027344
 MEAN (ABSOLUTE DIF.) = 1.46875
 STANDARD DEVIATION = 1.74076806
 90% CONFIDENCE LIMITS = -3.89481346 TO 1.83231346
 TOTAL OCCURRENCES = 32

CARRIER: BLUE DIRECTION: Westbound REGION: Middle Atlantic



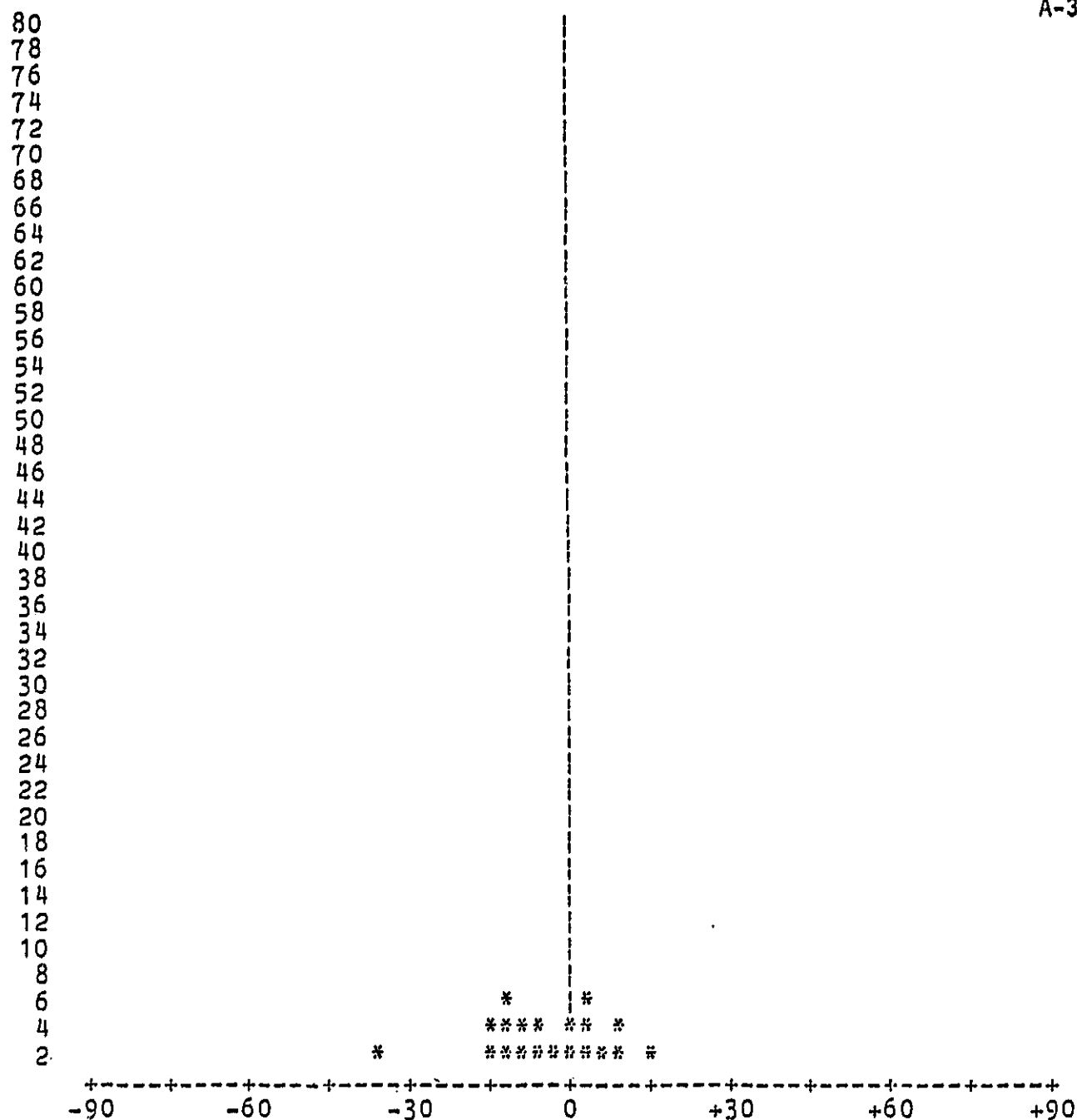
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Direction Difference in Degrees

Operational Segments MINUS AIDS Derived Segments

MEAN	=	.9375	
VARIANCE	=	5783.5586	
MEAN (ABSOLUTE DIF.)	=	56.75	
STANDARD DEVIATION	=	76.0497114	
90% CONFIDENCE LIMITS		-124.164275	TO 126.039275
TOTAL OCCURRENCES	=	32	

CARRIER: BLUE DIRECTION: Westbound REGION: Middle Atlantic



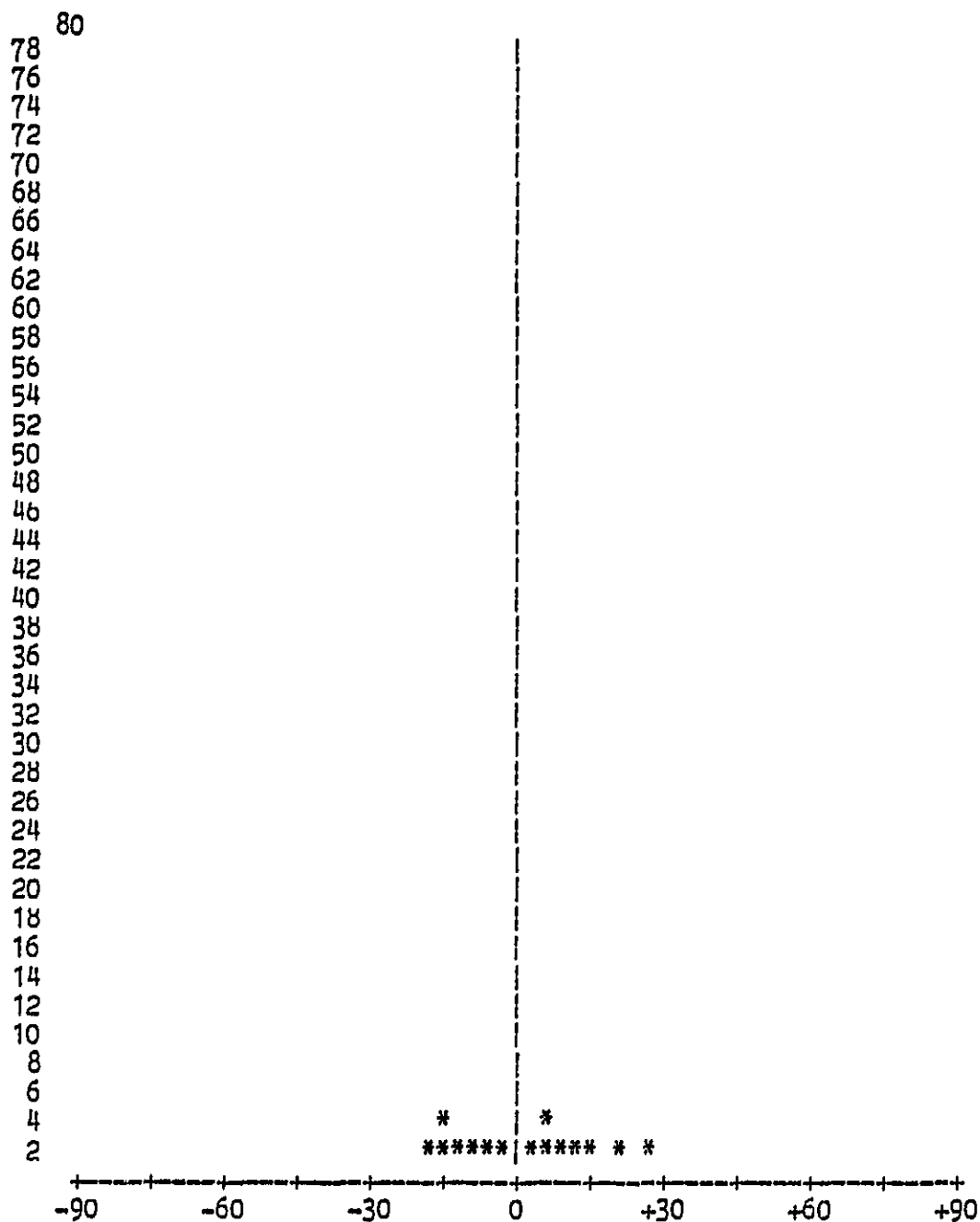
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Speed Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -5
 VARIANCE = 129.625
 MEAN (ABSOLUTE DIF.) = 9.4375
 STANDARD DEVIATION = 11.3852976
 90% CONFIDENCE LIMITS -23.7288145 TO 13.7288145
 TOTAL OCCURRENCES = 32

CARRIER: BLUE DIRECTION: Westbound REGION: Middle Atlantic



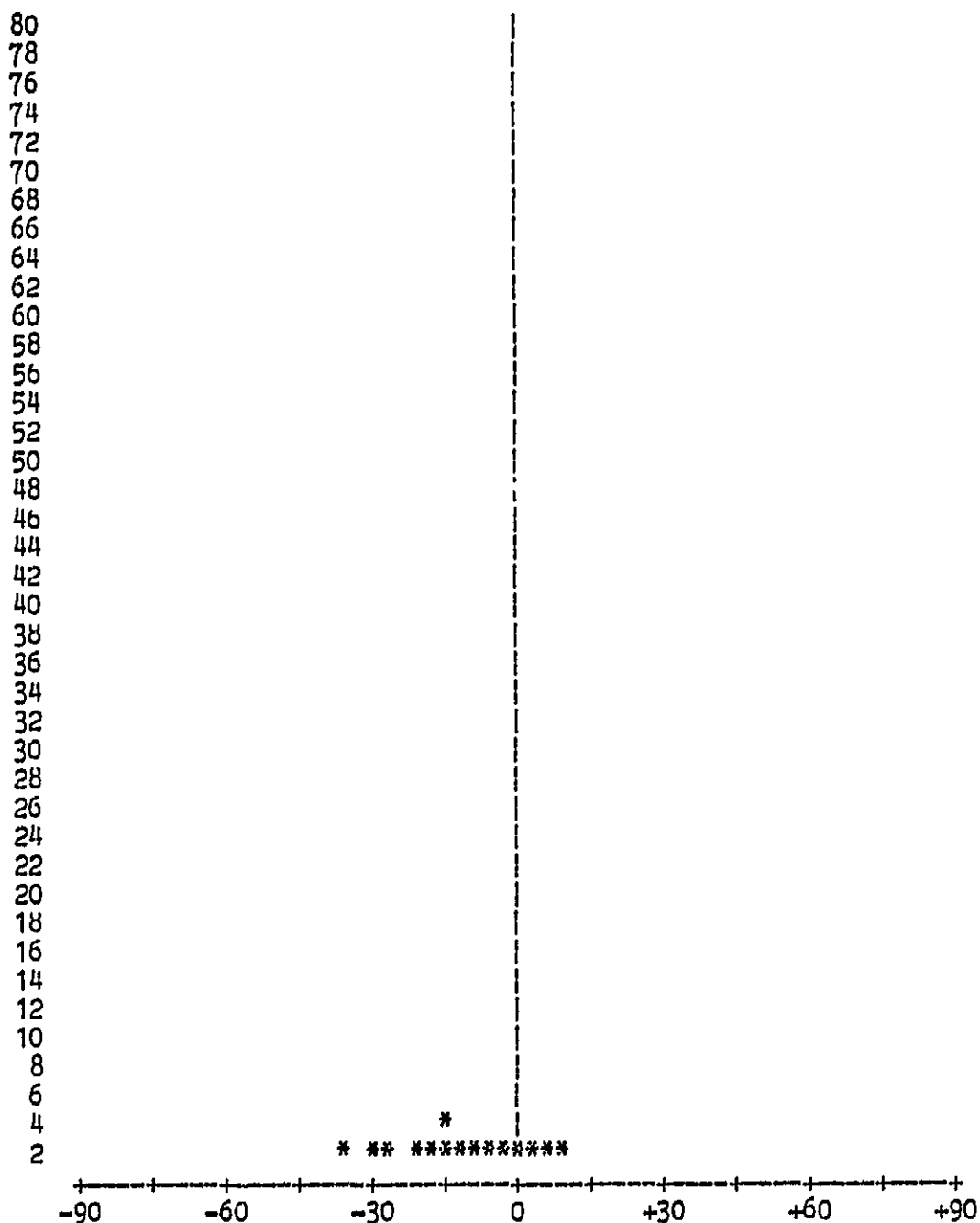
NUMBER OF OCCURRENCES BY DIFFERENCE

Cross-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = 0
 VARIANCE = 173.909091
 MEAN (ABSOLUTE DIF.) = 11.8181818
 STANDARD DEVIATION = 13.1874596
 90% CONFIDENCE LIMITS -21.6933711 TO 21.6933711
 TOTAL OCCURRENCES = 22

CARRIER: BLUE DIRECTION: Westbound REGION: Middle Atlantic



NUMBER OF OCCURRENCES BY DIFFERENCE

Parallel-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -10.4545455
 VARIANCE = 137.520661
 MEAN (ABSOLUTE DIF.) = 12.9090909
 STANDARD DEVIATION = 11.7269204
 90% CONFIDENCE LIMITS -29.7453295 TO 8.83623856
 TOTAL OCCURRENCES = 22

CARRIER: BLUE DIRECTION: Westbound REGION: Middle Atlantic

Operational Segments MINUS AIDS Derived Segments

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RMS of Vector Error = 33.6669438
TOTAL OCCURRENCES = 393

CARRIER: BLUE DIRECTION: Eastbound REGION: North Atlantic

Operational Segments MINUS AIDS Derived Segments

RMS of Vector Error = 33.607992
TOTAL OCCURRENCES = 696

CARRIER: BLUE DIRECTION: Westbound REGION: North Atlantic

Operational Segments MINUS AIDS Derived Segments

RMS of Vector Error = 38.3861955
TOTAL OCCURRENCES = 4

CARRIER: BLUE DIRECTION: Eastbound REGION: Polar

Operational Segments MINUS AIDS Derived Segments

RMS of Vector Error = 31.0074433
TOTAL OCCURRENCES = 13

CARRIER: BLUE DIRECTION: Westbound REGION: Polar

Operational Segments MINUS AIDS Derived Segments

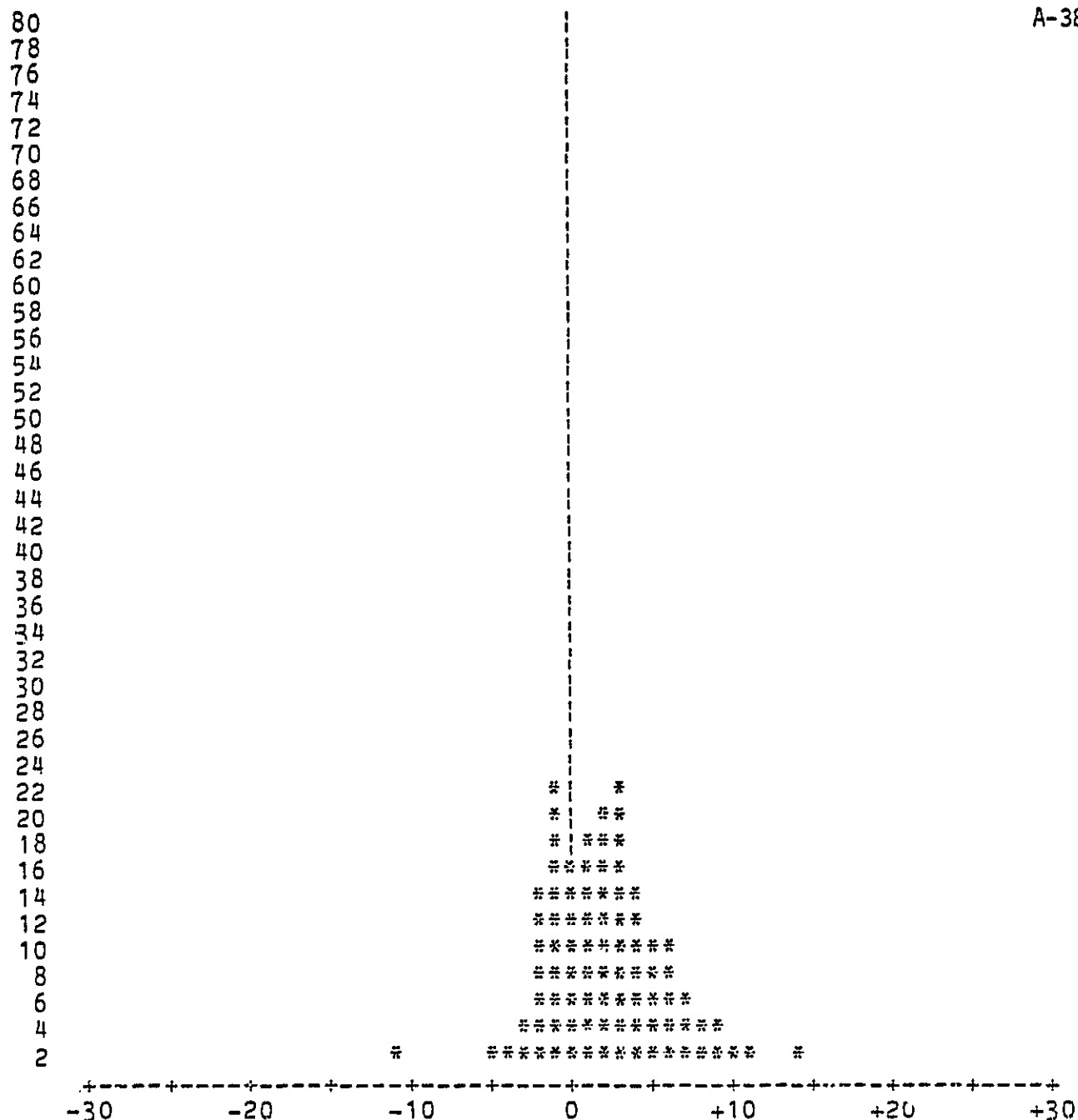
RMS of Vector Error = 23.3452351
TOTAL OCCURRENCES = 4

CARRIER: BLUE DIRECTION: Eastbound REGION: Middle Atlantic

Operational Segments MINUS AIDS Derived Segments

RMS of Vector Error = 20.3000224
TOTAL OCCURRENCES = 22

CARRIER: BLUE DIRECTION: Westbound REGION: Middle Atlantic



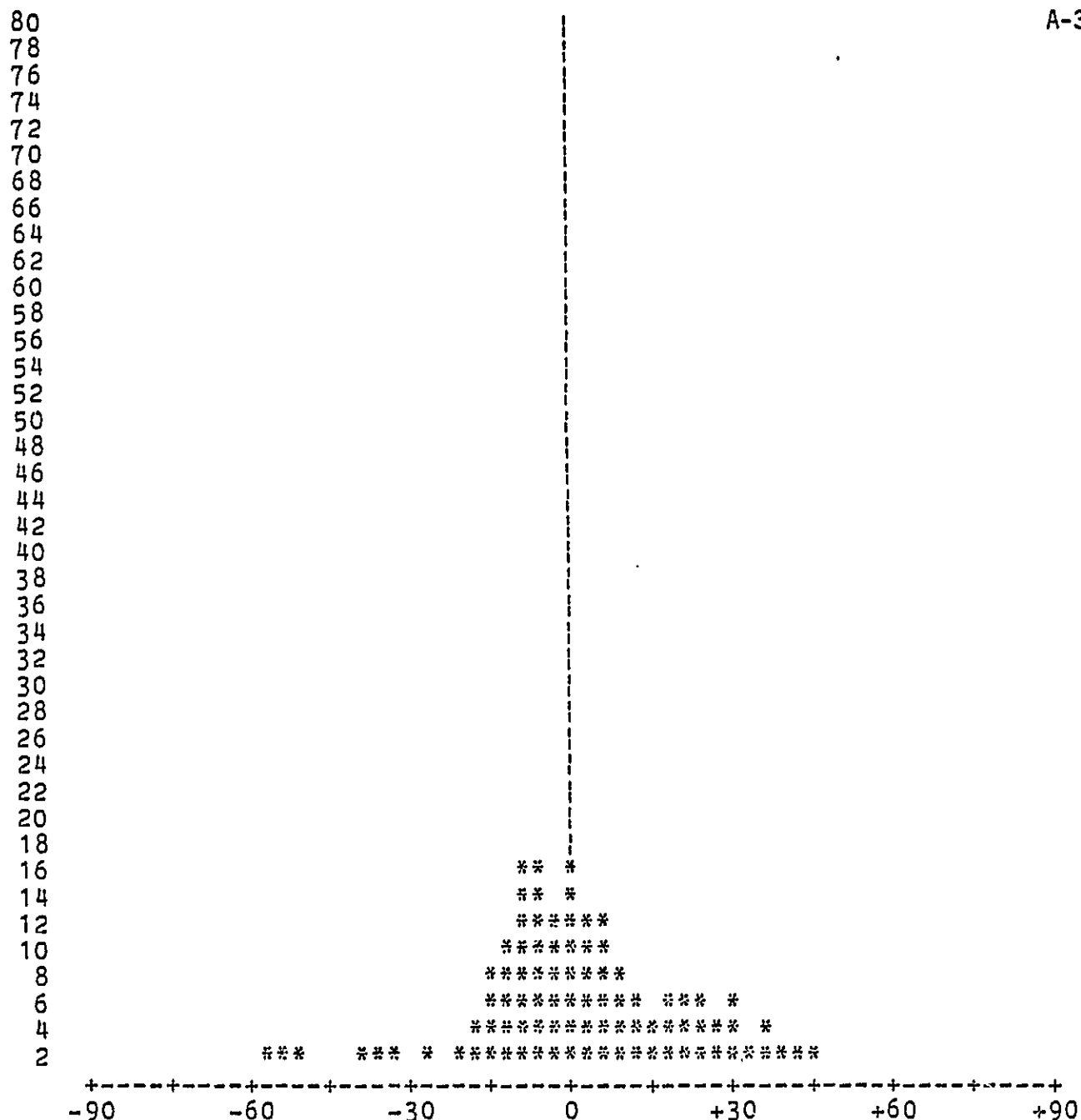
NUMBER OF OCCURRENCES BY DIFFERENCE

Temperature Difference in Degrees Centigrade

Operational Segments MINUS AIDS Derived Segments

MEAN = 1.96341463
 VARIANCE = 12.5718323
 MEAN (ABSOLUTE DIF.) = 3.07317073
 STANDARD DEVIATION = 3.54567797
 90% CONFIDENCE LIMITS -3.86922563 TO 7.79605489
 TOTAL OCCURRENCES = 164

CARRIER: RED DIRECTION: Eastbound REGION: North Atlantic



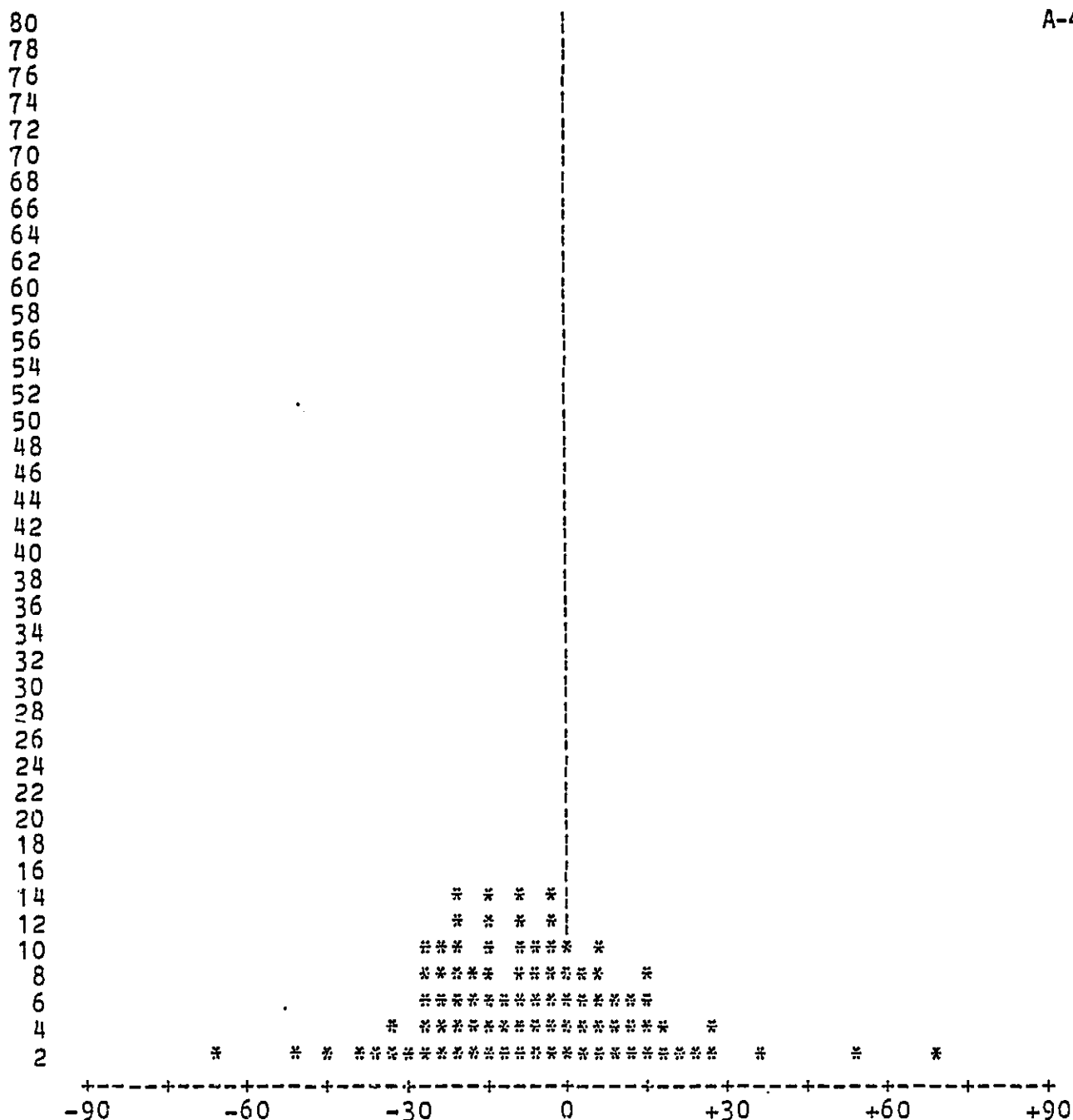
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Direction Difference in Degrees

Operational Segments MINUS AIDS Derived Segments

MEAN = 1.93939394
 VARIANCE = 321.911479
 MEAN (ABSOLUTE DIF.) = 13.4545455
 STANDARD DEVIATION = 17.9418917
 90% CONFIDENCE LIMITS -27.575018 TO 31.4538058
 TOTAL OCCURRENCES = 165

CARRIER: RED DIRECTION: Eastbound REGION: North Atlantic



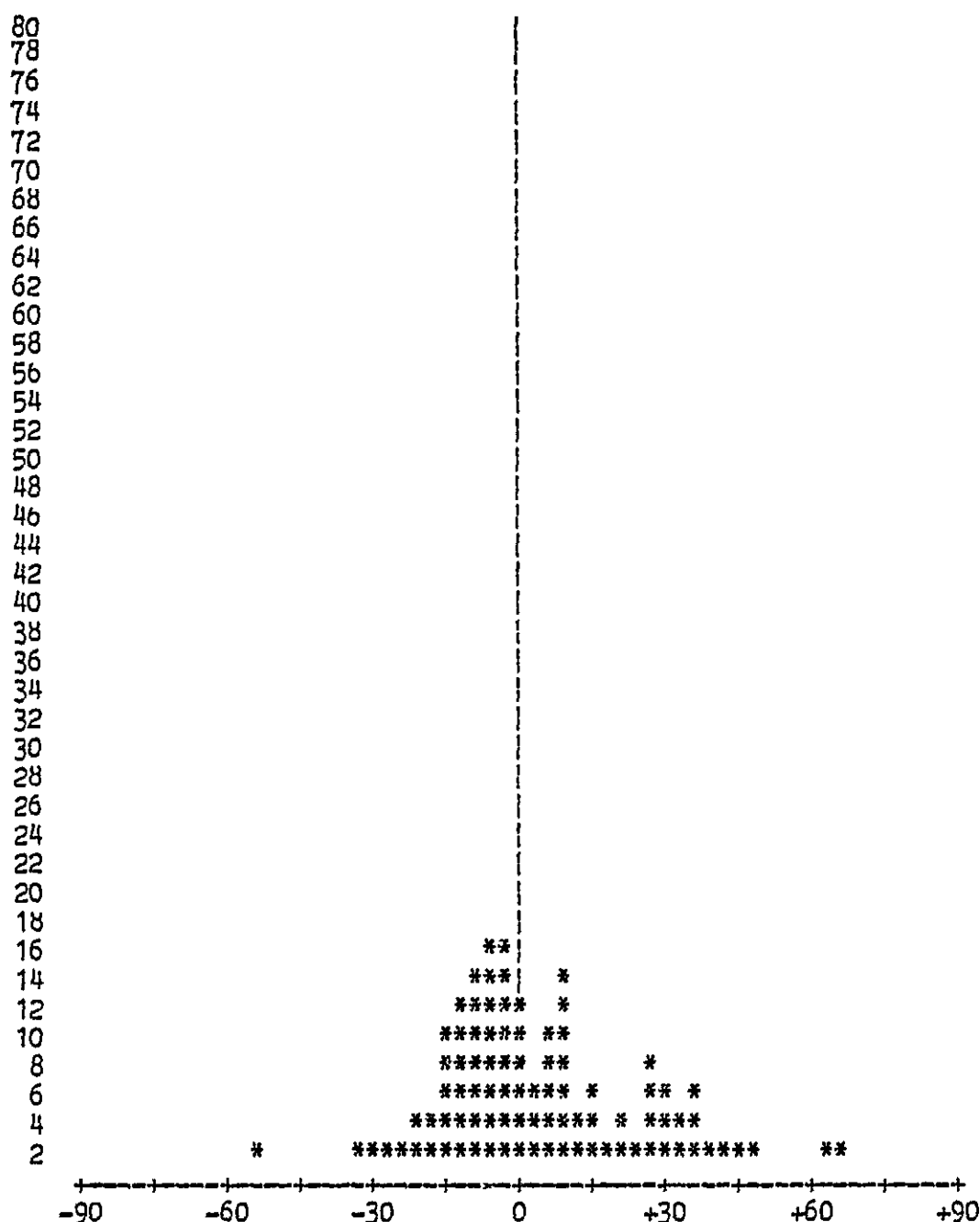
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Speed Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -6.3939394
 VARIANCE = 339.172085
 MEAN (ABSOLUTE DIF.) = 15.3393939
 STANDARD DEVIATION = 18.4166252
 90% CONFIDENCE LIMITS -36.6892879 TO 23.9014091
 TOTAL OCCURRENCES = 165

CARRIER: RED DIRECTION: Eastbound REGION: North Atlantic



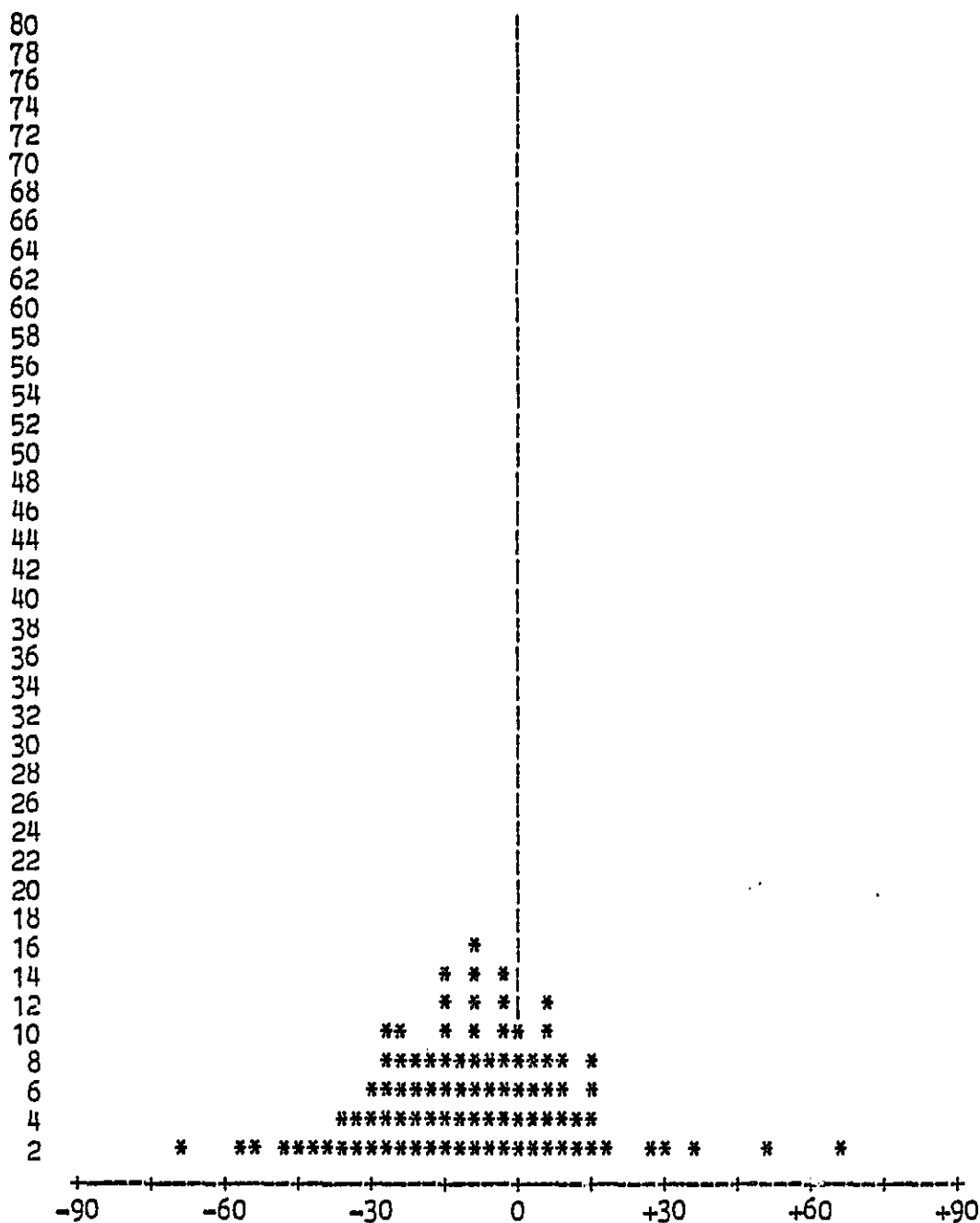
NUMBER OF OCCURRENCES BY DIFFERENCE

Cross-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = 3.35757576
 VARIANCE = 380.944868
 MEAN (ABSOLUTE DIF.) = 14.8121212
 STANDARD DEVIATION = 19.517809
 90% CONFIDENCE LIMITS -28.74922 TO 35.4643716
 TOTAL OCCURRENCES = 165

CARRIER: RED DIRECTION: Eastbound REGION: North Atlantic



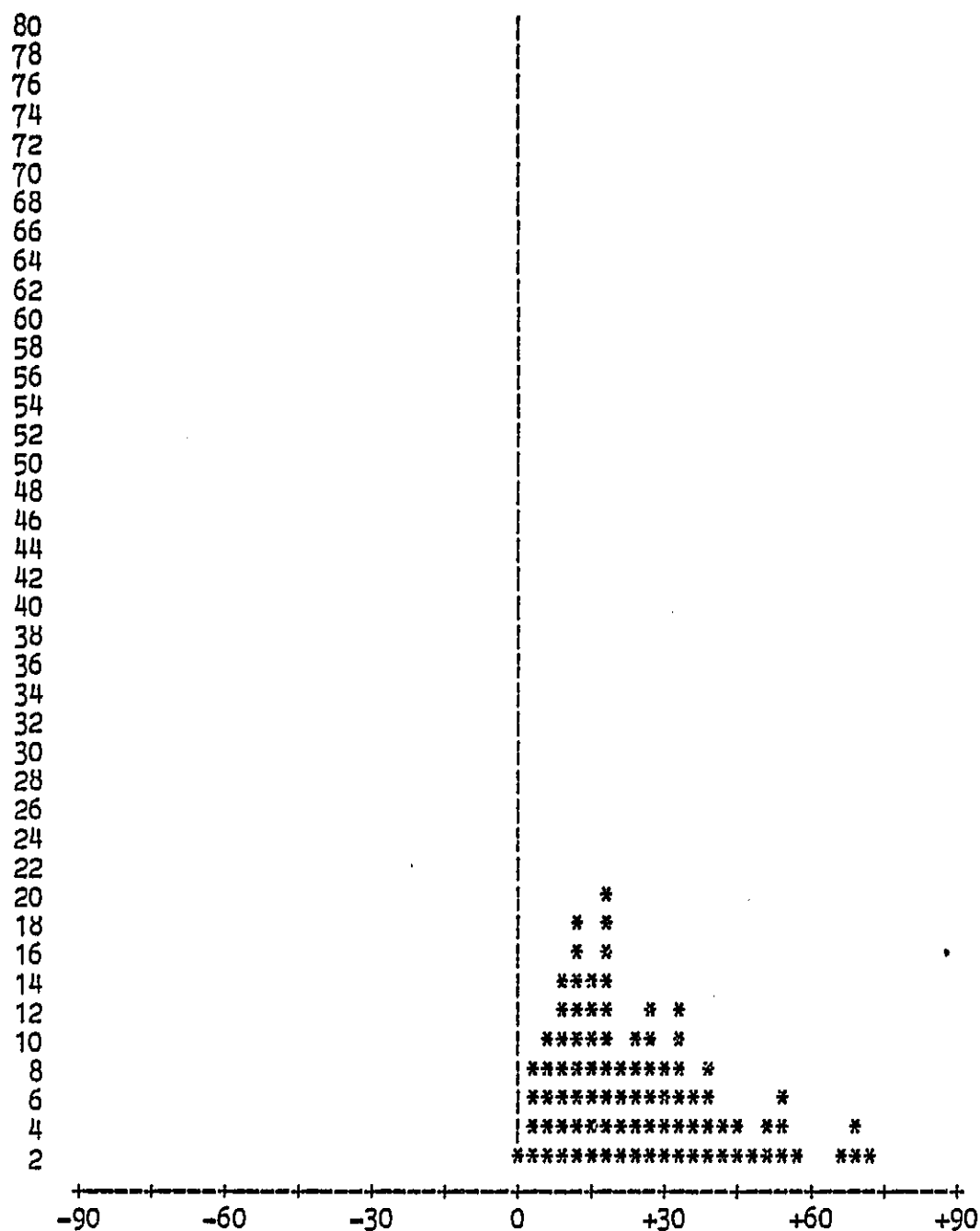
NUMBER OF OCCURRENCES BY DIFFERENCE

Parallel-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -9.20606061
 VARIANCE = 347.339358
 MEAN (ABSOLUTE DIF.) = 16.1272727
 STANDARD DEVIATION = 18.6370426
 90% CONFIDENCE LIMITS -39.8639957 TO 21.4518745
 TOTAL OCCURRENCES = 165

CARRIER: RED DIRECTION: Eastbound REGION: North Atlantic



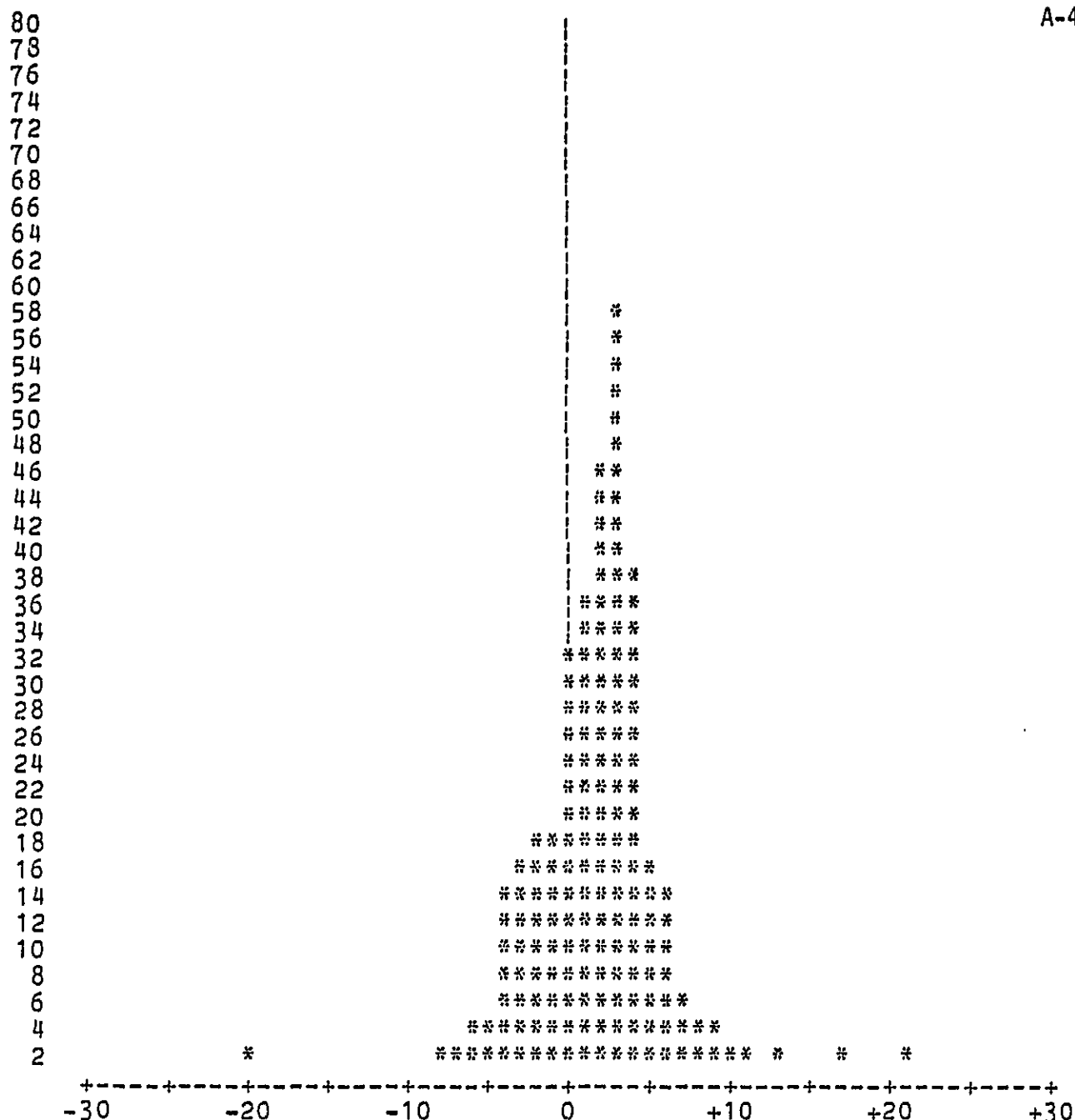
NUMBER OF OCCURRENCES BY DIFFERENCE

Magnitude of Vector Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = 23.9515152
 VARIANCE = 240.288559
 MEAN (ABSOLUTE DIF.) = 23.9515152
 STANDARD DEVIATION = 15.5012438
 90% CONFIDENCE LIMITS -1.54803086 TO 49.4510612
 TOTAL OCCURRENCES = 165

CARRIER: RED DIRECTION: Eastbound REGION: North Atlantic



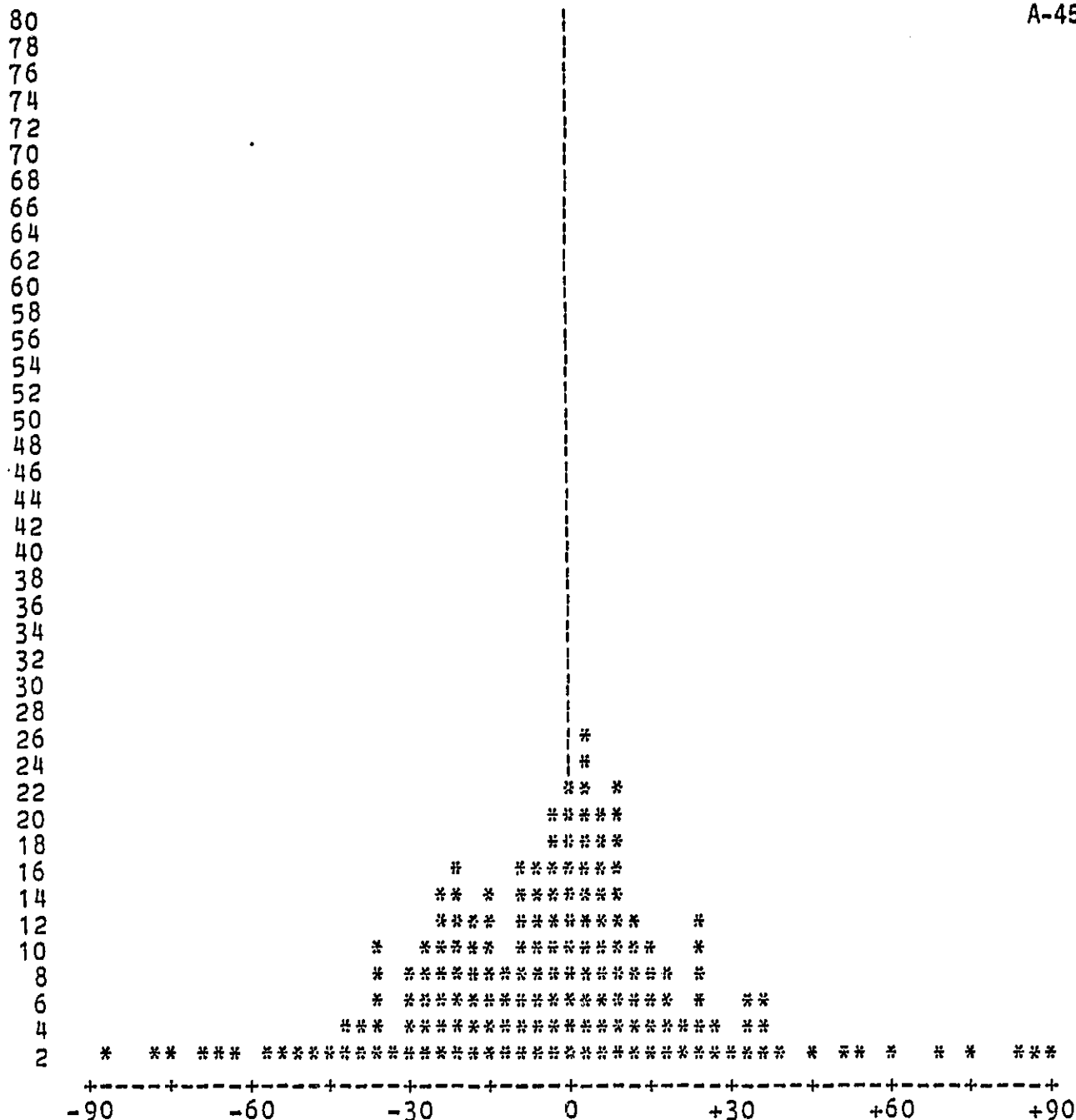
NUMBER OF OCCURRENCES BY DIFFERENCE

Temperature Difference in Degrees Centigrade

Operational Segments MINUS AIDS Derived Segments

MEAN = 1.6941896
 VARIANCE = 13.0746757
 MEAN (ABSOLUTE DIF.) = 3.04587156
 STANDARD DEVIATION = 3.61589211
 90% CONFIDENCE LIMITS -4.25395292 TO 7.64233213
 TOTAL OCCURRENCES = 327

CARRIER: RED DIRECTION: Westbound REGION: North Atlantic



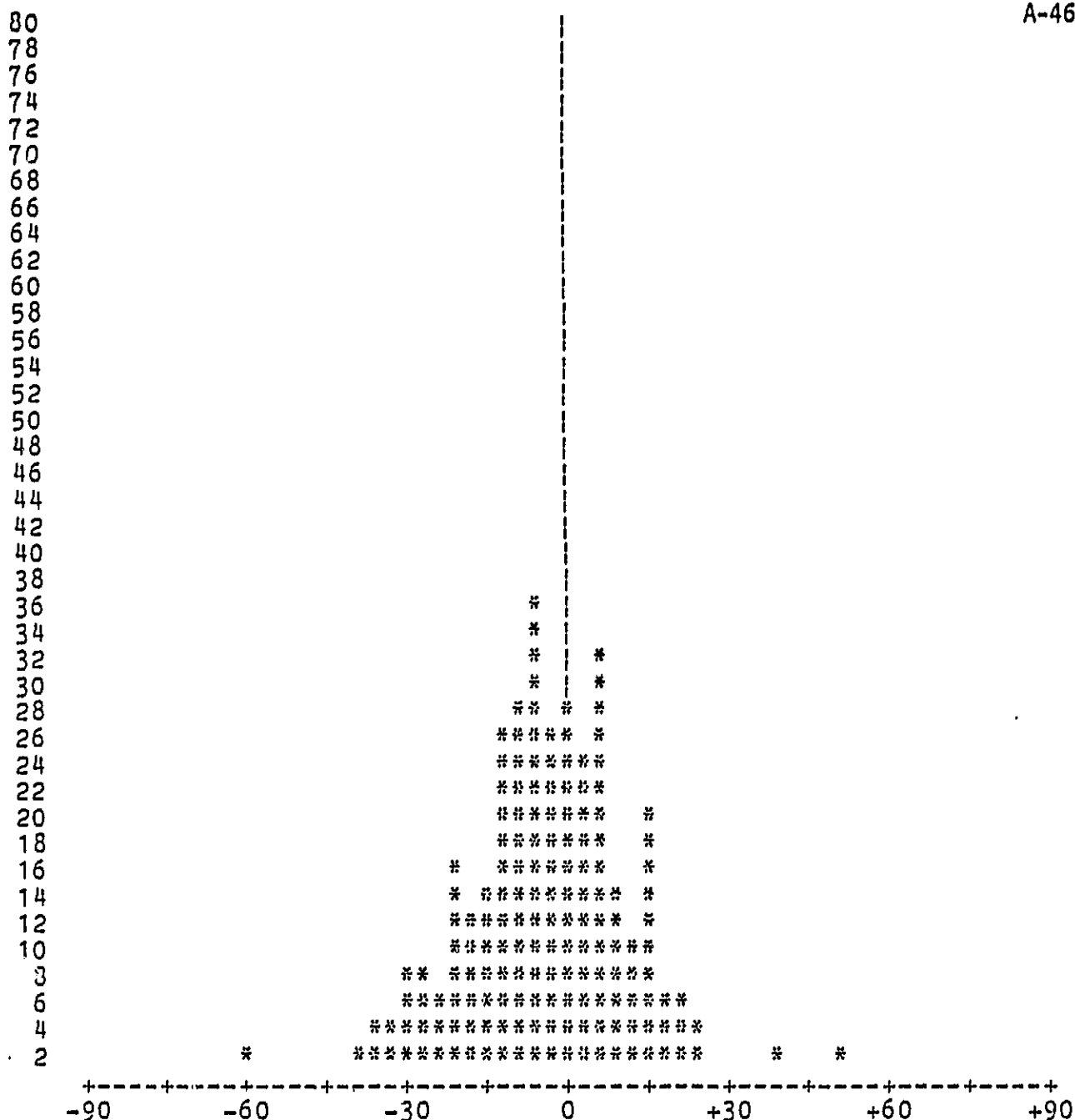
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Direction Difference in Degrees

Operational Segments MINUS AIDS Derived Segments

MEAN = -2.03669725
 VARIANCE = 1142.64086
 MEAN (ABSOLUTE DIF.) = 21.706422
 STANDARD DEVIATION = 33.8029711
 90% CONFIDENCE LIMITS = -57.6425848 TO 53.5691903
 TOTAL OCCURRENCES = 327

CARRIER: RED DIRECTION: Westbound REGION: North Atlantic

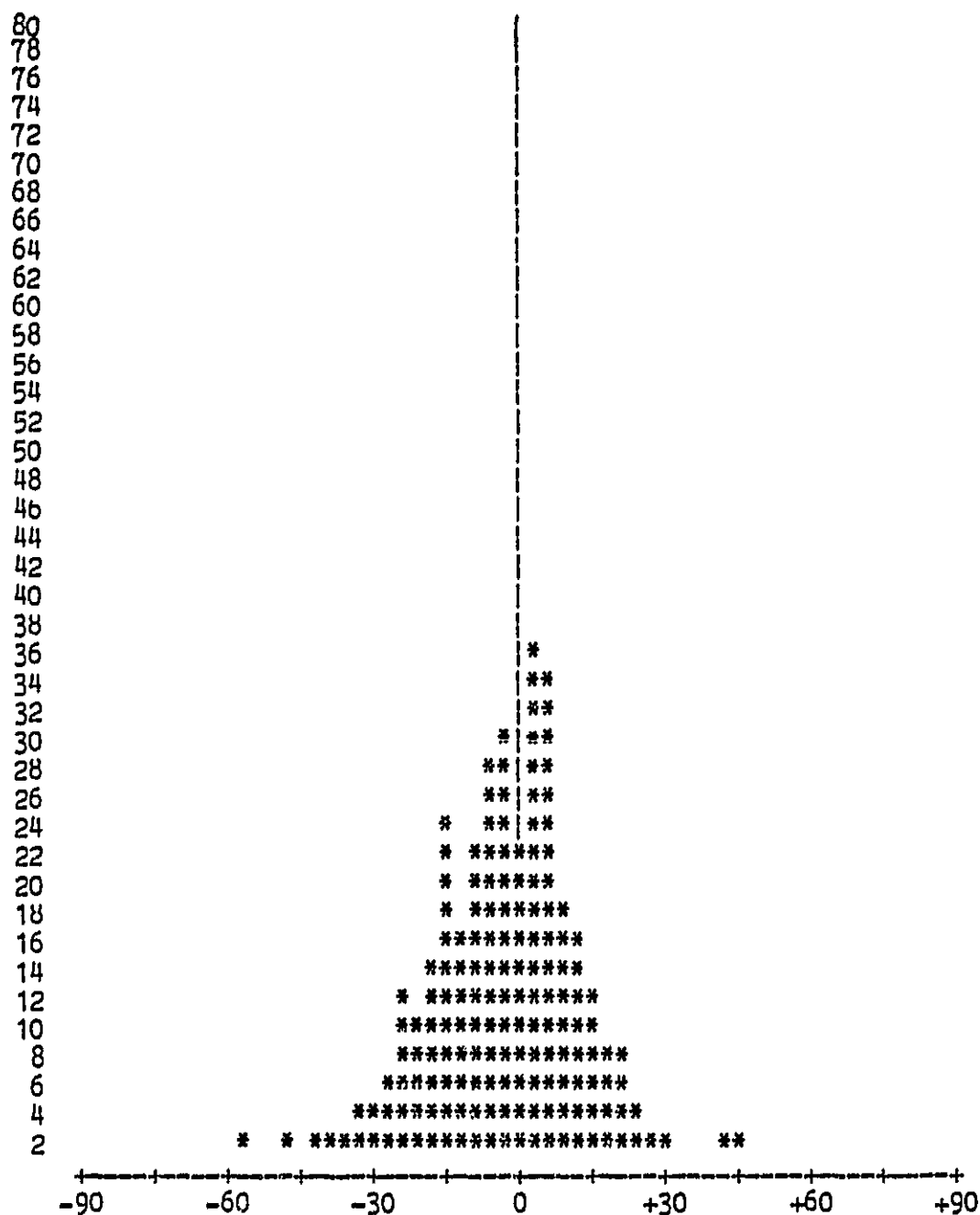


Wind Speed Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -4.24464832
 VARIANCE = 206.723022
 MEAN (ABSOLUTE DIF.) = 11.4984709
 STANDARD DEVIATION = 14.3778657
 90% CONFIDENCE LIMITS = -27.8962374 TO 19.4069408
 TOTAL OCCURRENCES = 327

CARRIER: RED DIRECTION: Westbound REGION: North Atlantic



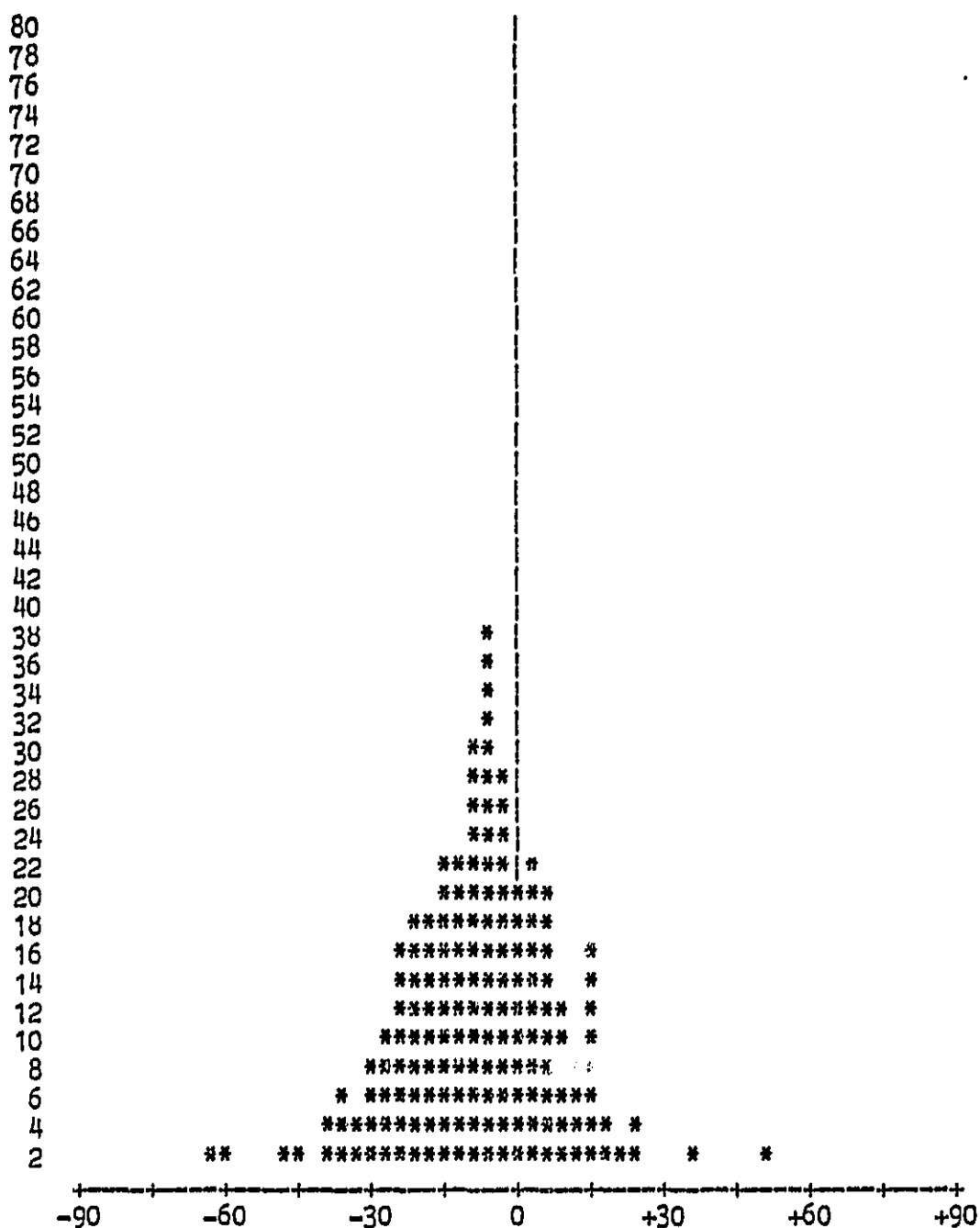
NUMBER OF OCCURRENCES BY DIFFERENCE

Cross-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -3.11009174
 VARIANCE = 210.948125
 MEAN (ABSOLUTE DIF.) = 11.3363914
 STANDARD DEVIATION = 14.5240533
 90% CONFIDENCE LIMITS -27.0021595 TO 20.781976
 TOTAL OCCURRENCES = 327

CARRIER: RED DIRECTION: Westbound REGION: North Atlantic



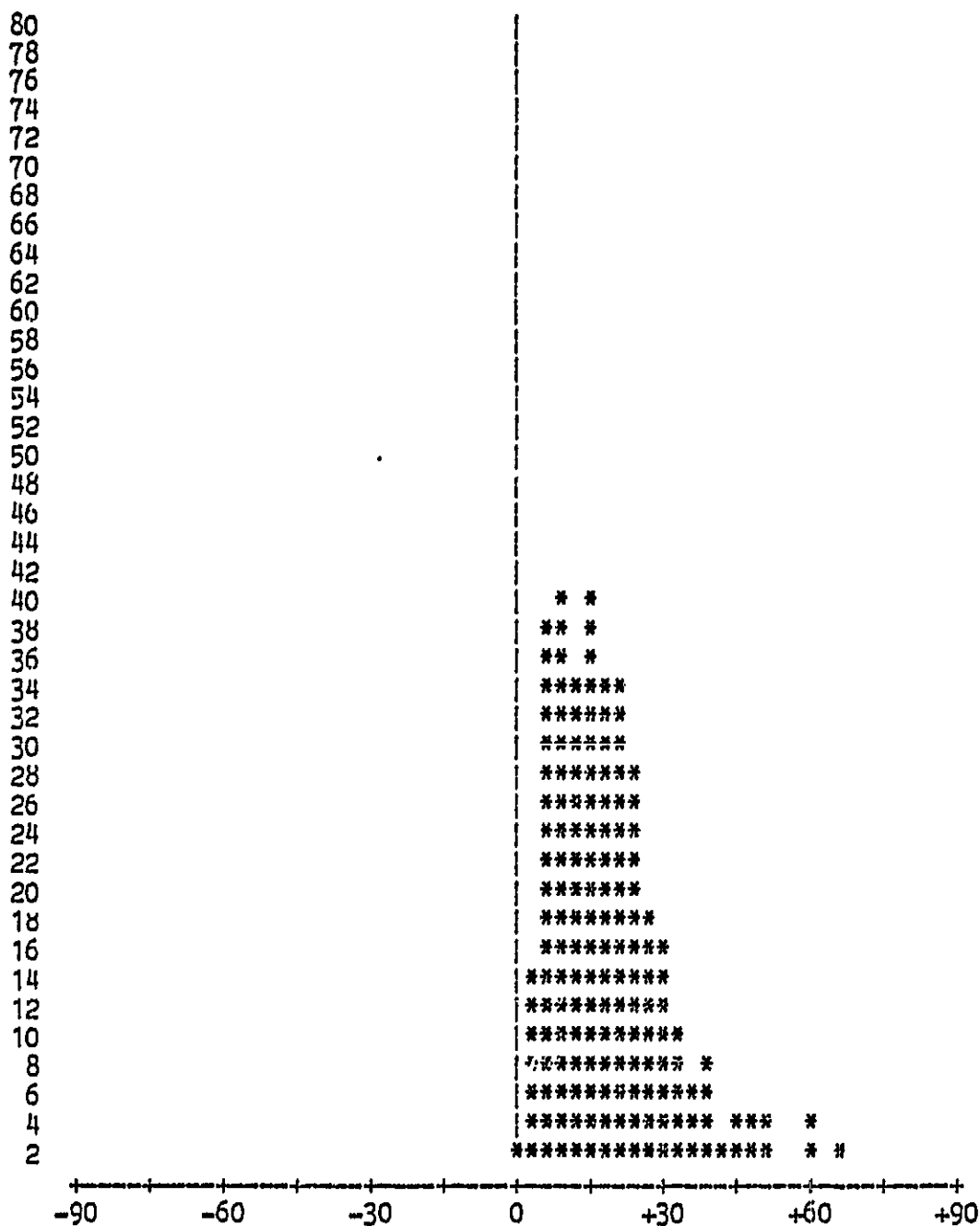
NUMBER OF OCCURRENCES BY DIFFERENCE

Parallel-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -7.55045872
 VARIANCE = 217.091491
 MEAN (ABSOLUTE DIF.) = 12.8470948
 STANDARD DEVIATION = 14.7340249
 90% CONFIDENCE LIMITS -31.7879298 TO 16.6870123
 TOTAL OCCURRENCES = 327

CARRIER: RED DIRECTION: Westbound REGION: North Atlantic



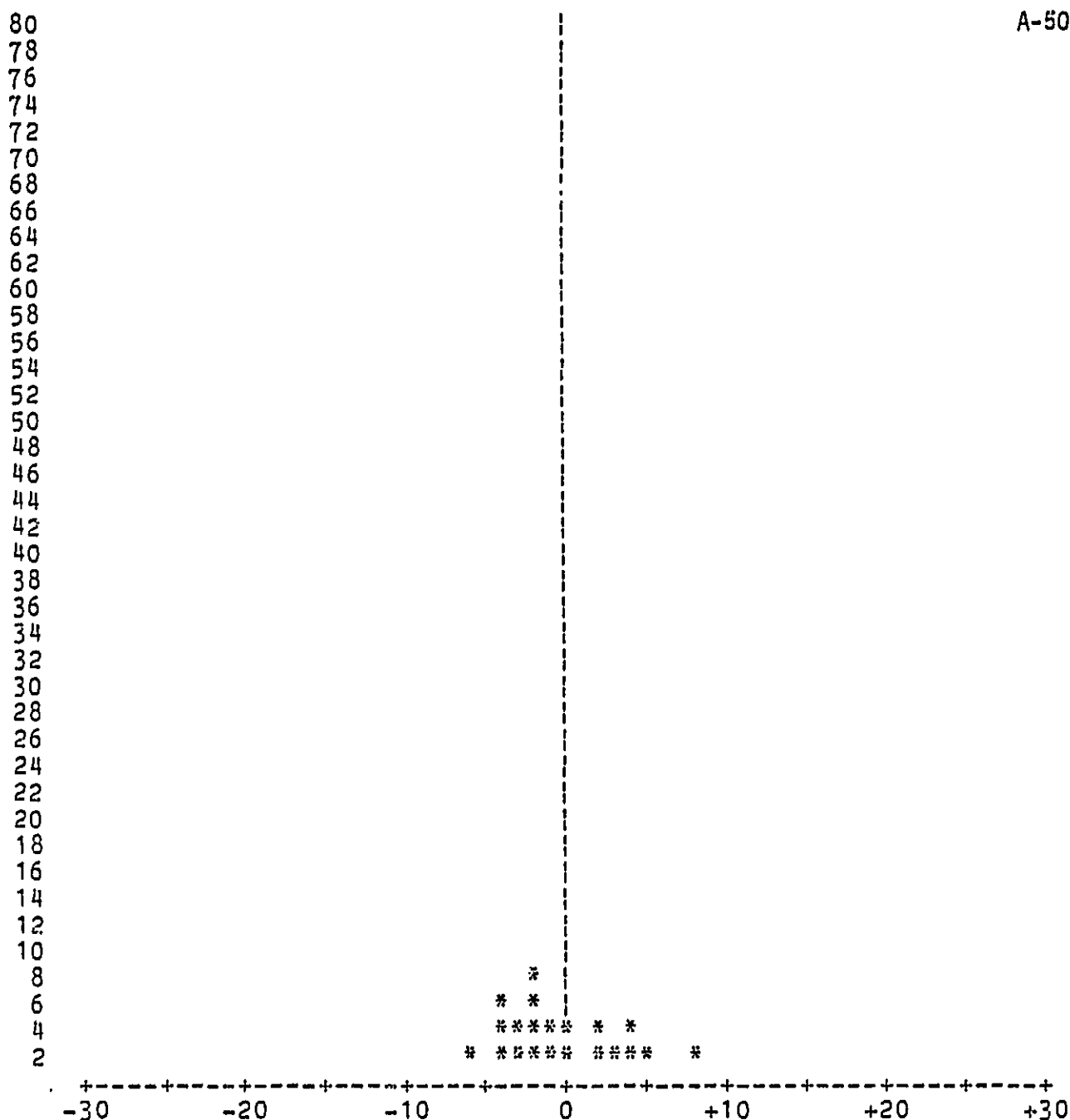
NUMBER OF OCCURRENCES BY DIFFERENCE

Magnitude of Vector Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = 18.6636086
 VARIANCE = 131.788982
 MEAN (ABSOLUTE DIF.) = 18.6636086
 STANDARD DEVIATION = 11.4799382
 90% CONFIDENCE LIMITS = -22.0889824 TO 37.548107
 TOTAL OCCURRENCES = 327

CARRIER: RED DIRECTION: Westbound REGION: North Atlantic



NUMBER OF OCCURRENCES BY DIFFERENCE

Temperature Difference in Degress Centigrade

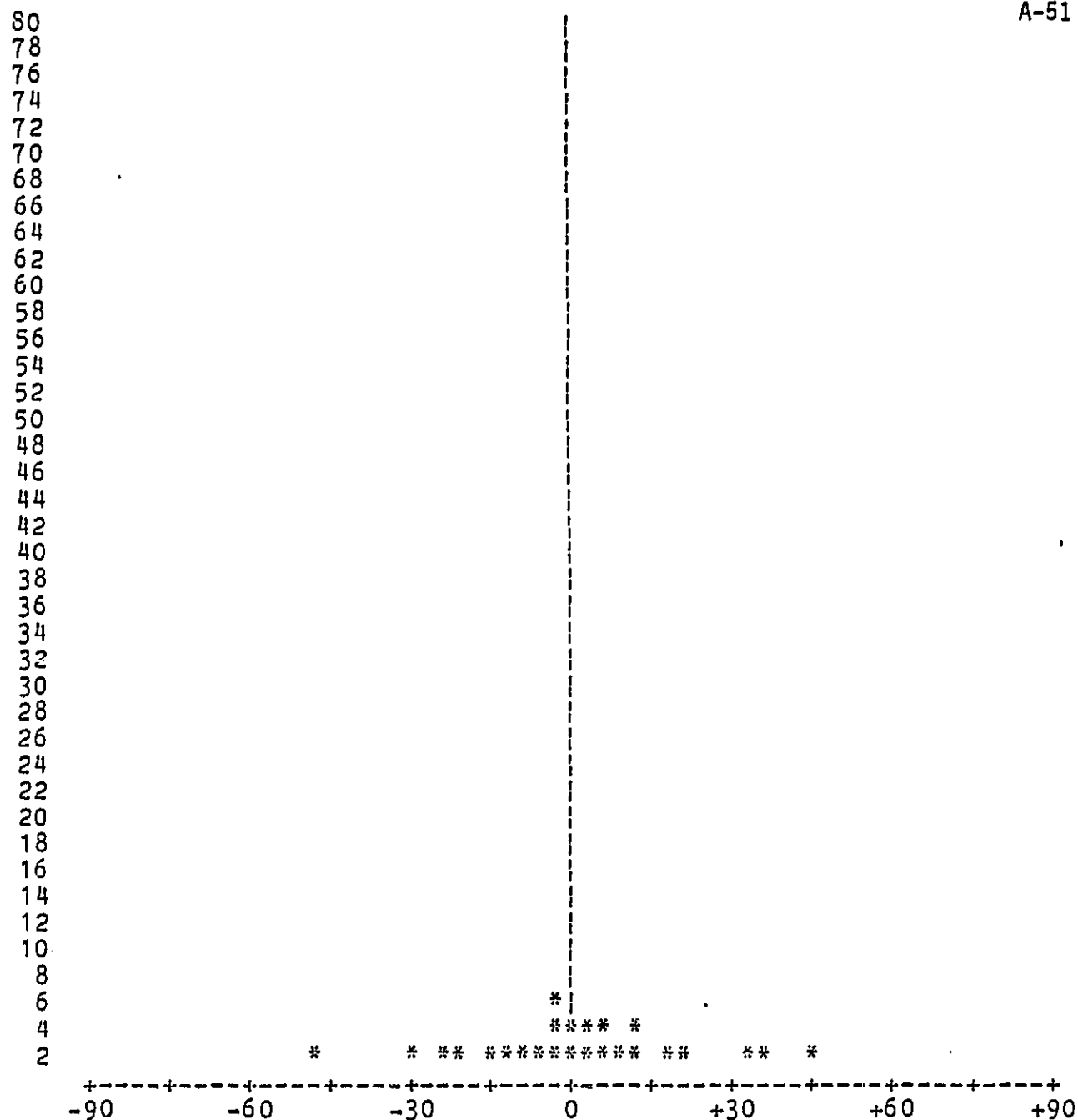
Operational Segments MINUS AIDS Derived Segments

MEAN = -.694444444
 VARIANCE = 10.2677469
 MEAN (ABSOLUTE DIF.)= 2.75
 STANDARD DEVIATION = 3.20433252
 90% CONFIDENCE LIMITS = -5.96557145 TO 4.57668256
 TOTAL OCCURRENCES = 36

CARRIER: RED

DIRECTION: Eastbound

REGION: Polar



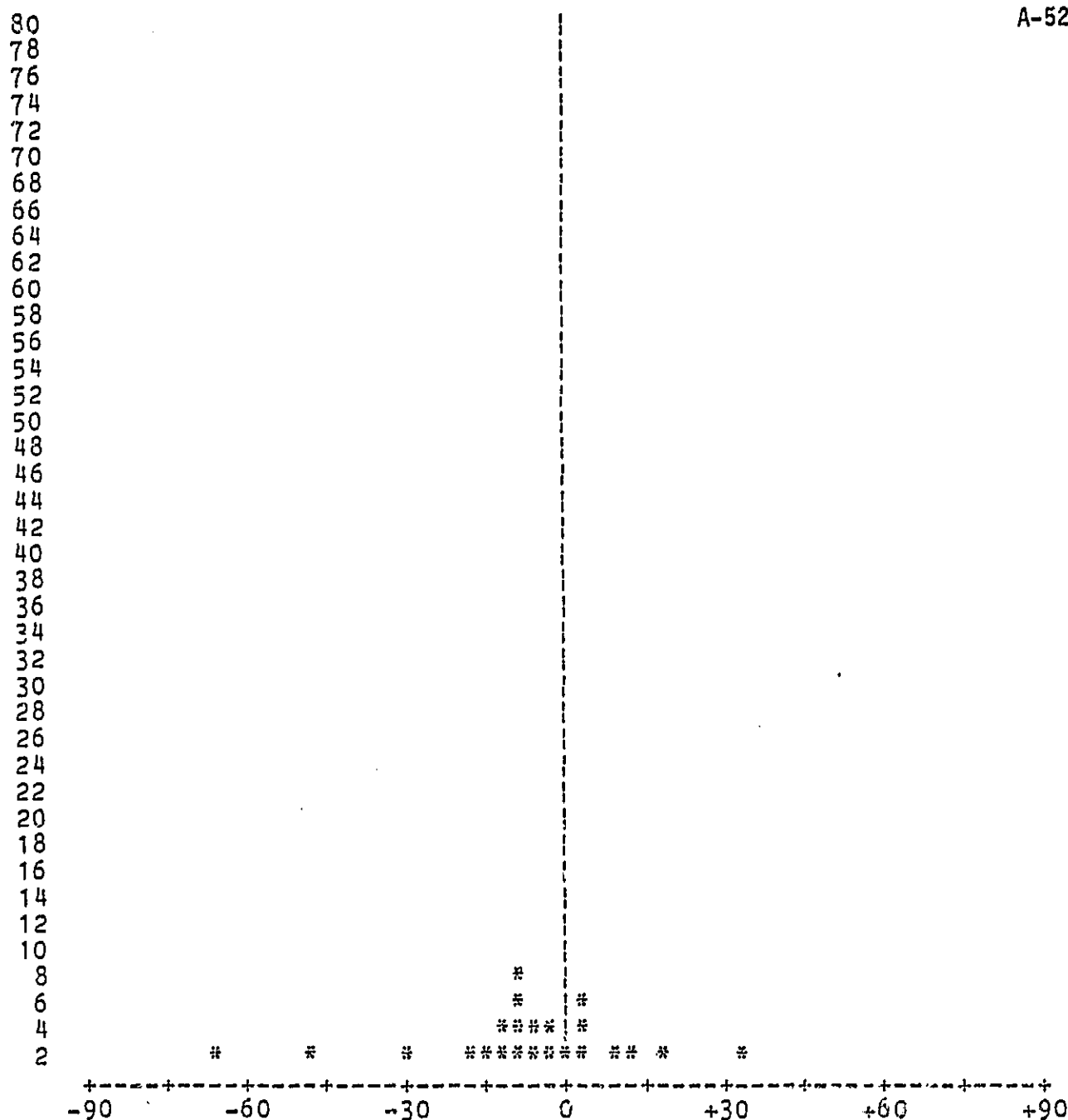
NUMBER OF OCCURRENCES P. DIFFERENCE

Wind Direction Difference in Degrees

Operational Segments MINUS AIDS Derived Segments

MEAN = -3.80555556
 VARIANCE = 1738.26775
 MEAN (ABSOLUTE DIF.) = 22.25
 STANDARD DEVIATION = 41.6925383
 90% CONFIDENCE LIMITS = -72.3897811 TO 64.7786699
 TOTAL OCCURRENCES = 36

CARRIER: RED DIRECTION: Eastbound REGION: Polar



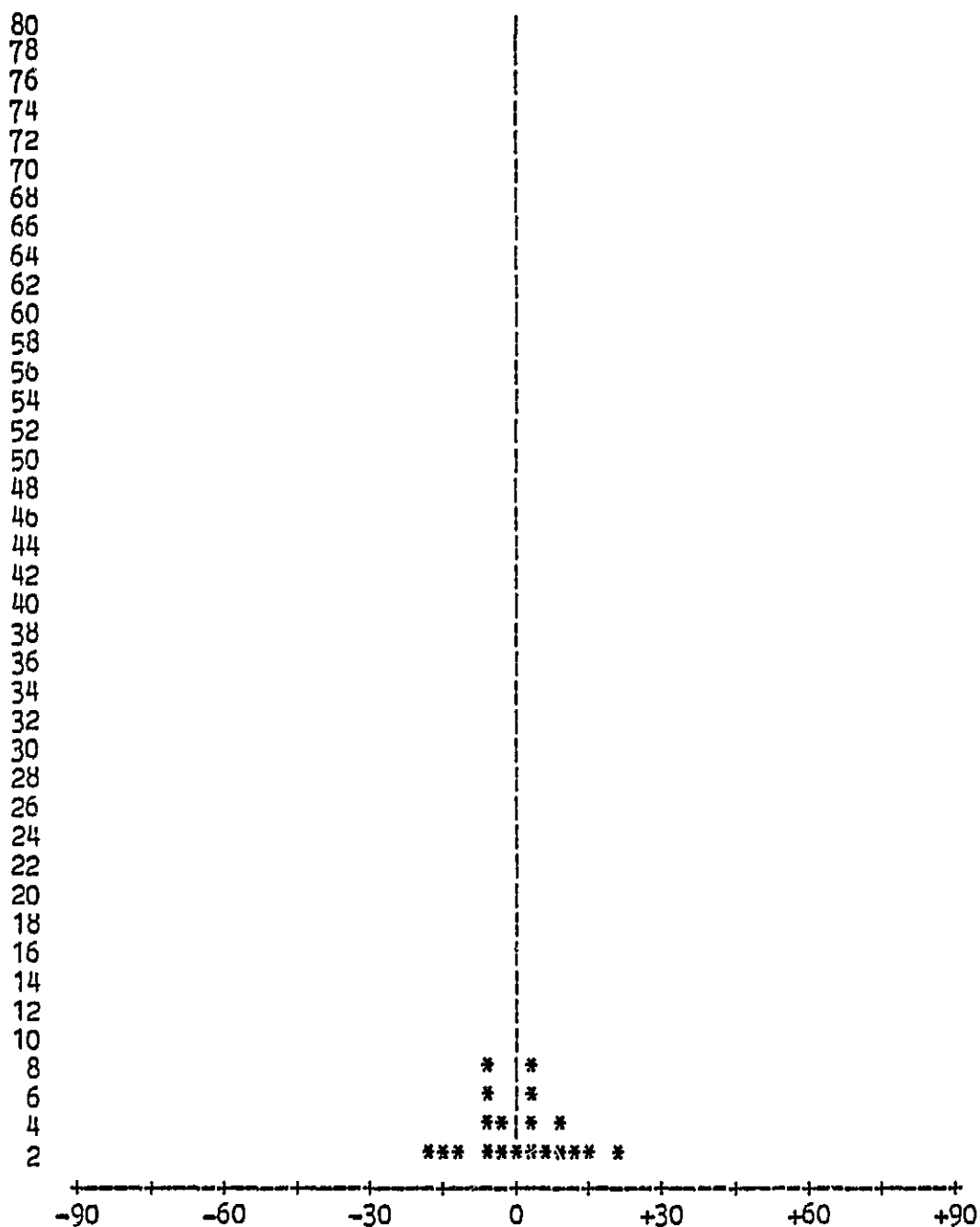
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Speed Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -5.7222223
 VARIANCE = 308.811729
 MEAN (ABSOLUTE DIF.) = 12.3888889
 STANDARD DEVIATION = 17.5730398
 90% CONFIDENCE LIMITS -34.6298728 TO 23.1854283
 TOTAL OCCURRENCES = 36

CARRIER: RED DIRECTION: Eastbound REGION: Polar



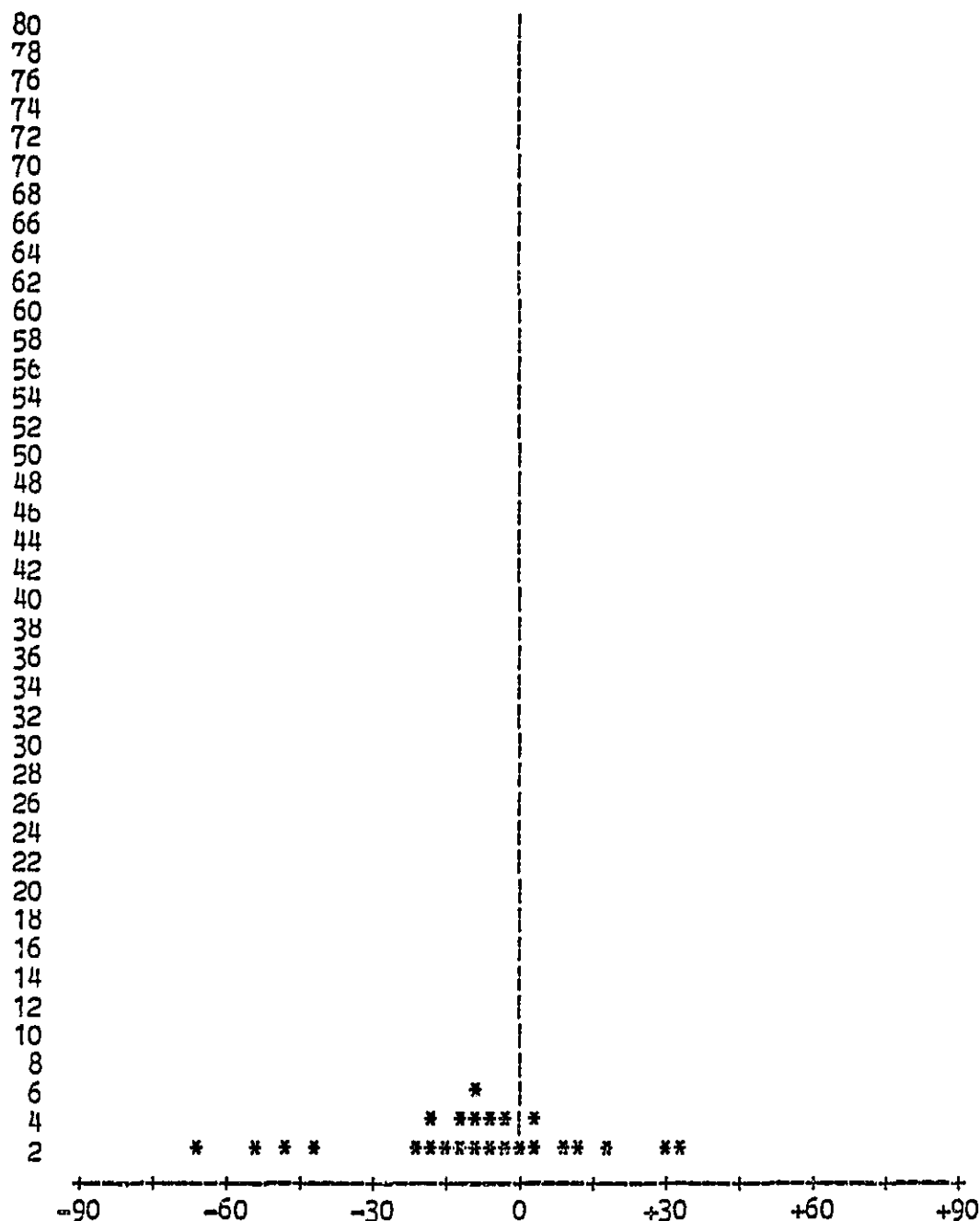
NUMBER OF OCCURRENCES BY DIFFERENCE

Cross-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = .63888889
 VARIANCE = 92.73071
 MEAN (ABSOLUTE DIF.) = 7.58333334
 STANDARD DEVIATION = 9.62967861
 90% CONFIDENCE LIMITS -15.2019324 TO 16.4797102
 TOTAL OCCURRENCES = 36

CARRIER: RED DIRECTION: Eastbound REGION: Polar



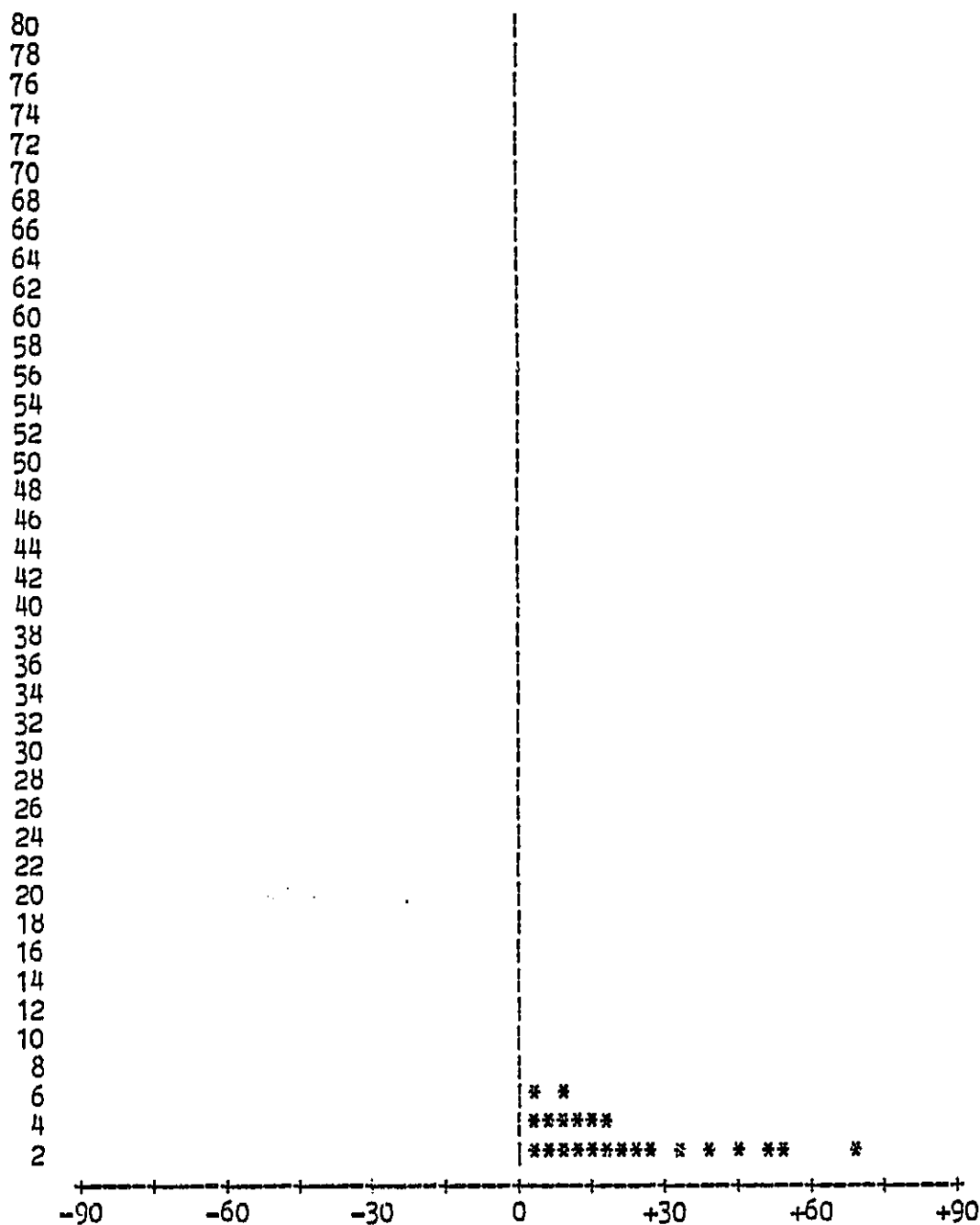
NUMBER OF OCCURRENCES BY DIFFERENCE

Parallel-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -8.72222223
 VARIANCE = 400.533951
 MEAN (ABSOLUTE DIF.) = 15.1111111
 STANDARD DEVIATION = 20.0133443
 90% CONFIDENCE LIMITS -41.6441737 TO 24.1997292
 TOTAL OCCURRENCES = 36

CARRIER: RED DIRECTION: Eastbound REGION: Polar



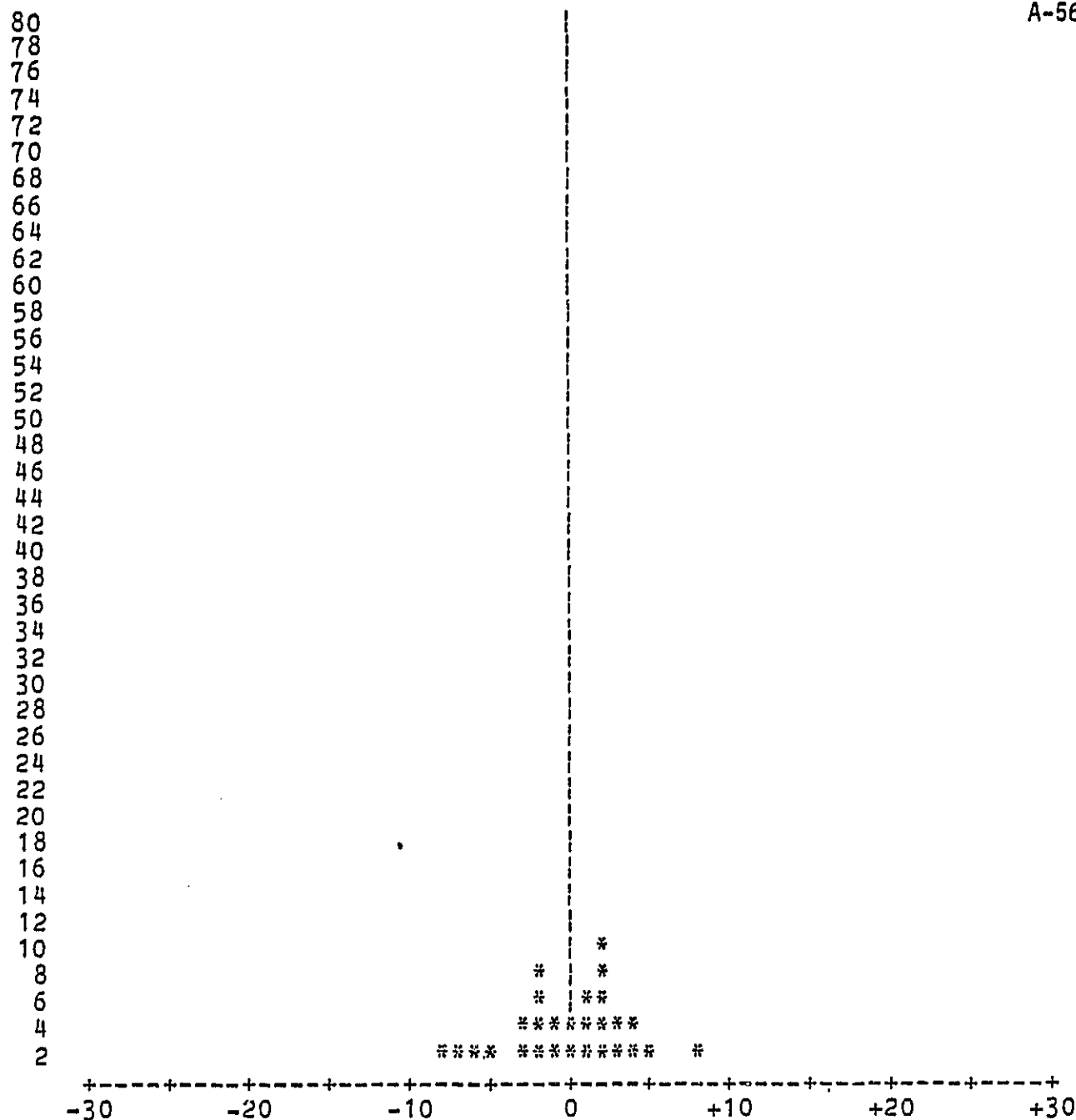
NUMBER OF OCCURRENCES BY DIFFERENCE

Magnitude of Vector Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN	=	18.0833333	
VARIANCE	=	240.465278	
MEAN (ABSOLUTE DIF.)	=	18.0833333	
STANDARD DEVIATION	=	15.5069429	
90% CONFIDENCE LIMITS		-7.42558775	TO 43.5922544
TOTAL OCCURRENCES	=	36	

CARRIER: RED DIRECTION: Eastbound REGION: Polar



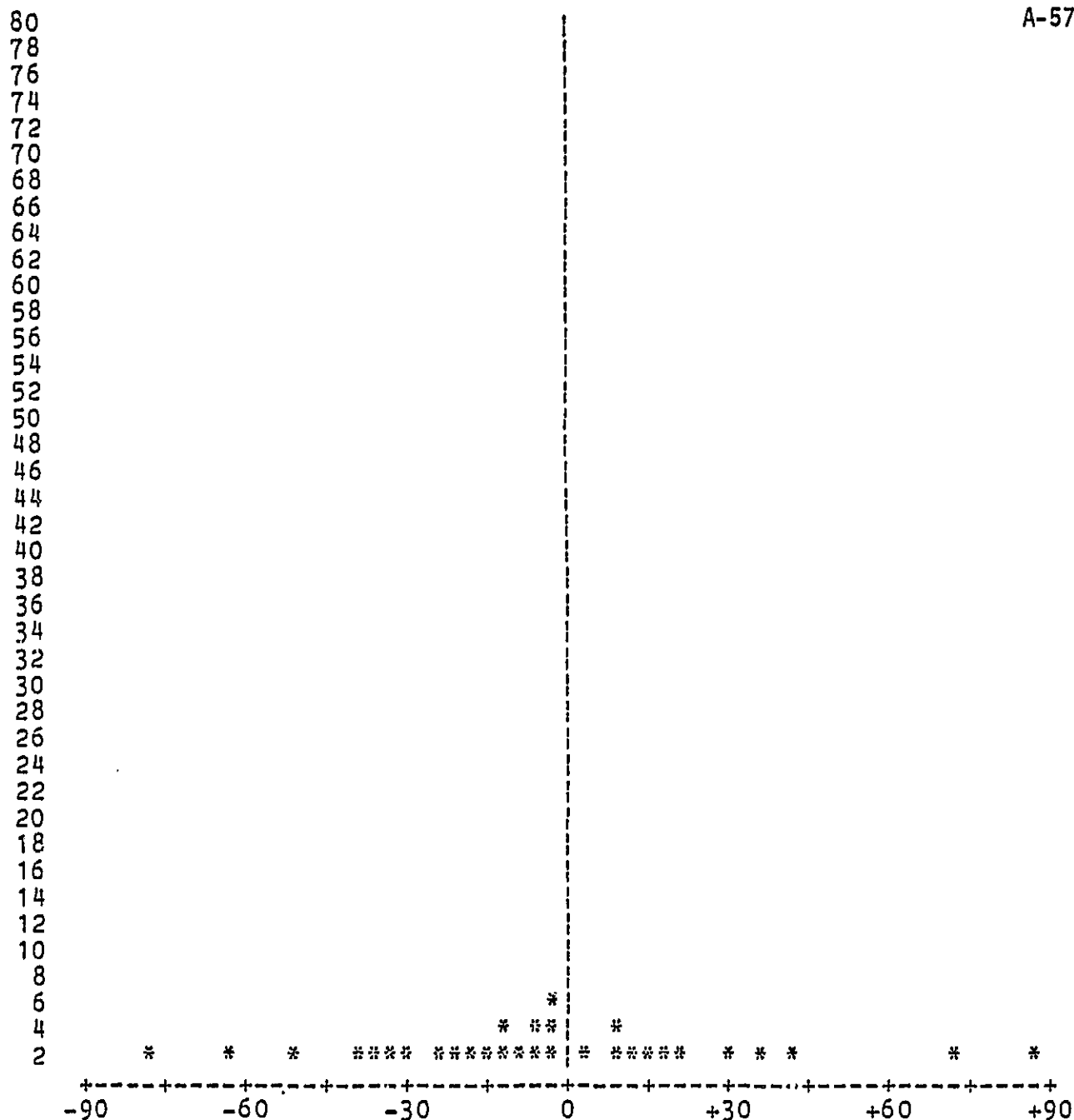
NUMBER OF OCCURRENCES BY DIFFERENCE

Temperature Difference in Degress Centigrade

Operational Segments MINUS AIDS Derived Segments

MEAN	=	.391304348	
VARIANCE	=	11.1077505	
MEAN (ABSOLUTE DIF.)	=	2.65217391	
STANDARD DEVIATION	=	3.3328292	
90% CONFIDENCE LIMITS		-5.09119969	TO 5.87380838
TOTAL OCCURRENCES	=	46	

CARRIER: RED DIRECTION: Westbound REGION: Polar



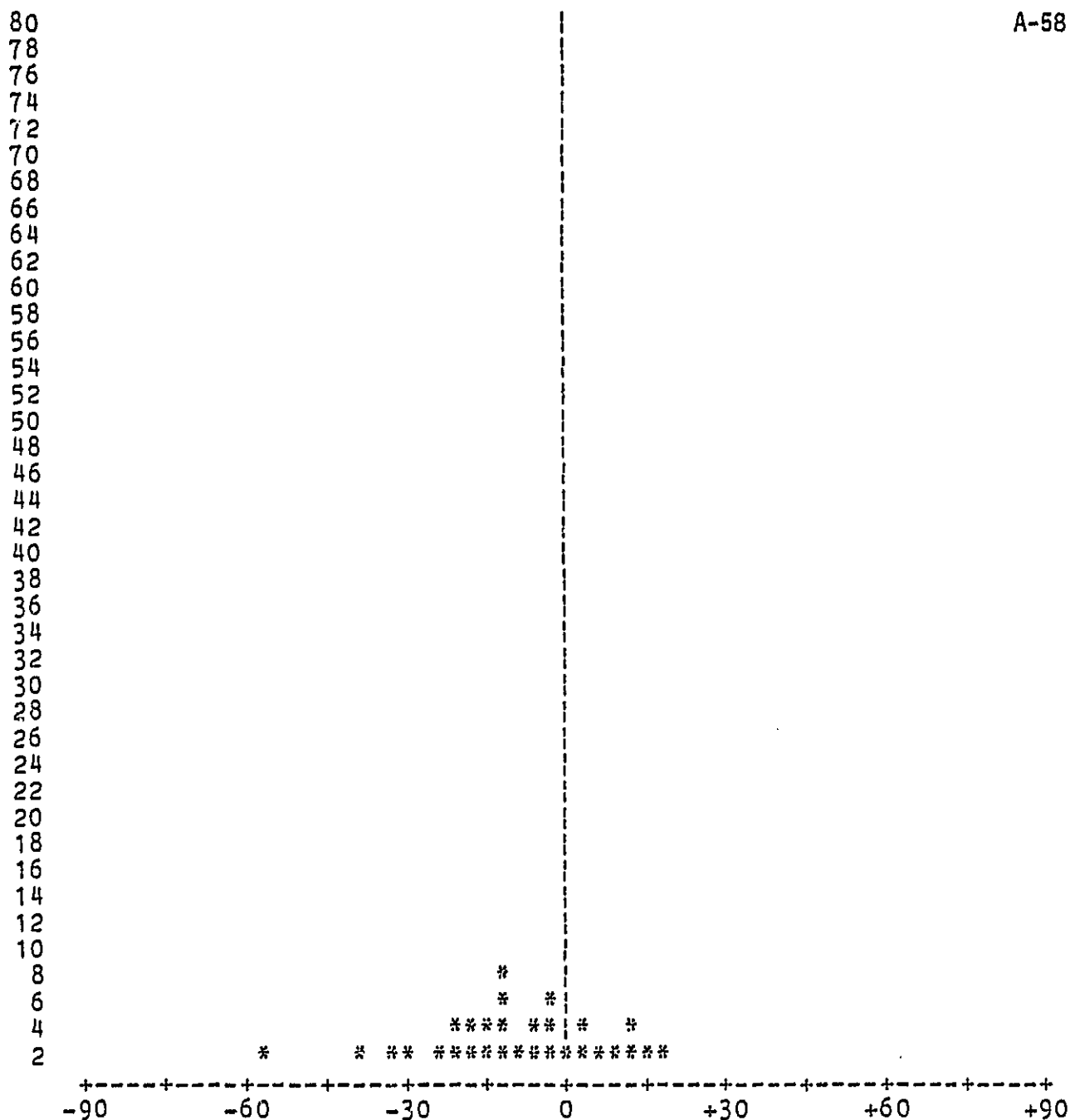
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Direction Difference in Degrees

Operational Segments MINUS AIDS Derived Segments

MEAN	=	-2.61702128	
VARIANCE	=	1122.32141	
MEAN (ABSOLUTE DIF.)	=	24.787234	
STANDARD DEVIATION	=	33.5010659	
90% CONFIDENCE LIMITS		-57.7262746	TO 52.4922321
TOTAL OCCURRENCES	=	47	

CARRIER: RED DIRECTION: Westbound REGION: Polar



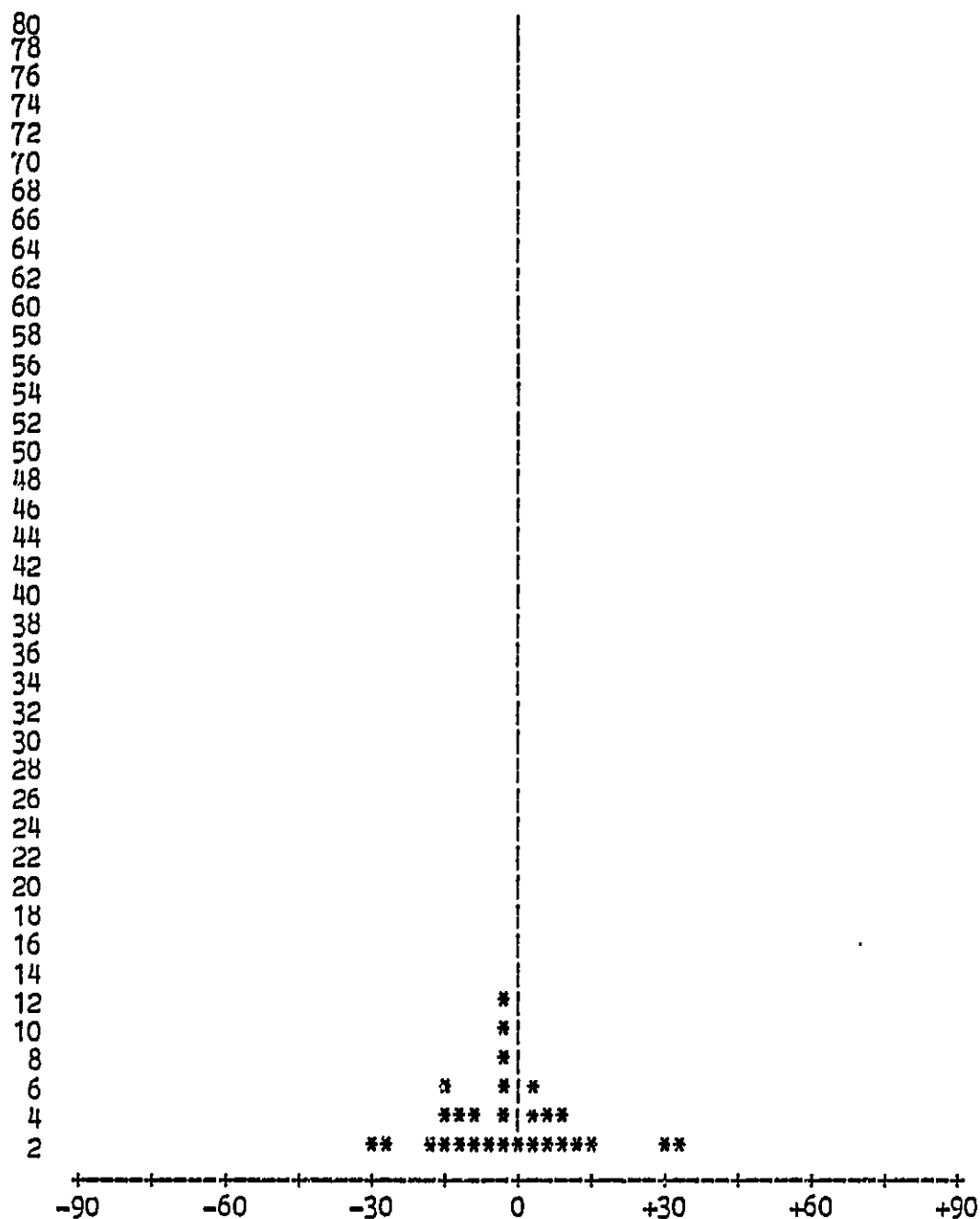
NUMBER OF OCCURRENCES BY DIFFERENCE

Wind Speed Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN	=	-9.14893617	
VARIANCE	=	233.616116	
MEAN (ABSOLUTE DIF.)	=	14	
STANDARD DEVIATION	=	15.2845058	
90% CONFIDENCE LIMITS		-34.2919482	TO 15.9940758
TOTAL OCCURRENCES	=	47	

CARRIER: RED DIRECTION: Westbound REGION: Polar



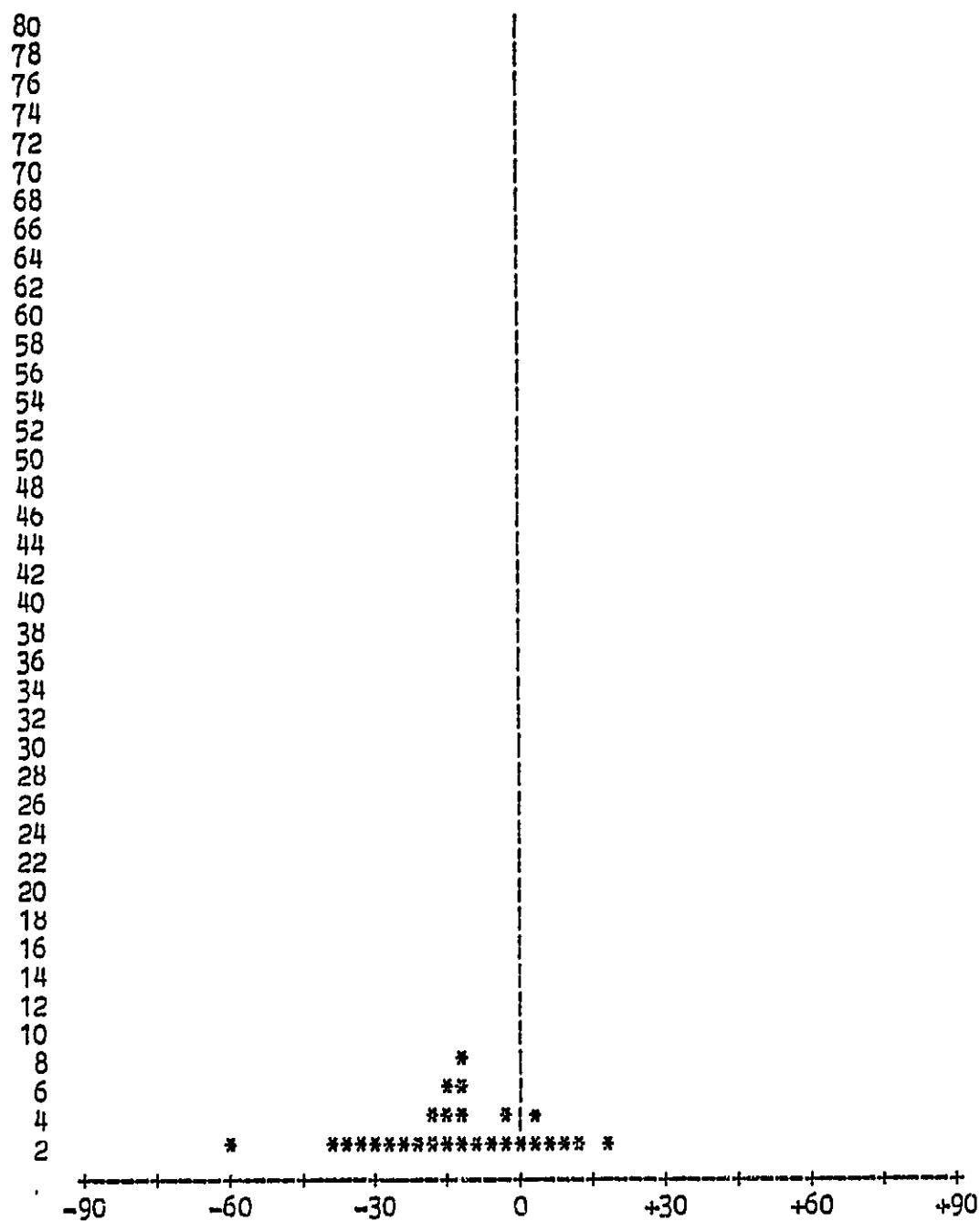
NUMBER OF OCCURRENCES BY DIFFERENCE

Cross-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -2
 VARIANCE = 141.191489
 MEAN (ABSOLUTE DIF.) = 9.19148937
 STANDARD DEVIATION = 11.8824025
 90% CONFIDENCE LIMITS -21.5465521 TO 17.5465521
 TOTAL OCCURRENCES = 47

CARRIER: RED DIRECTION: Westbound REGION: Polar



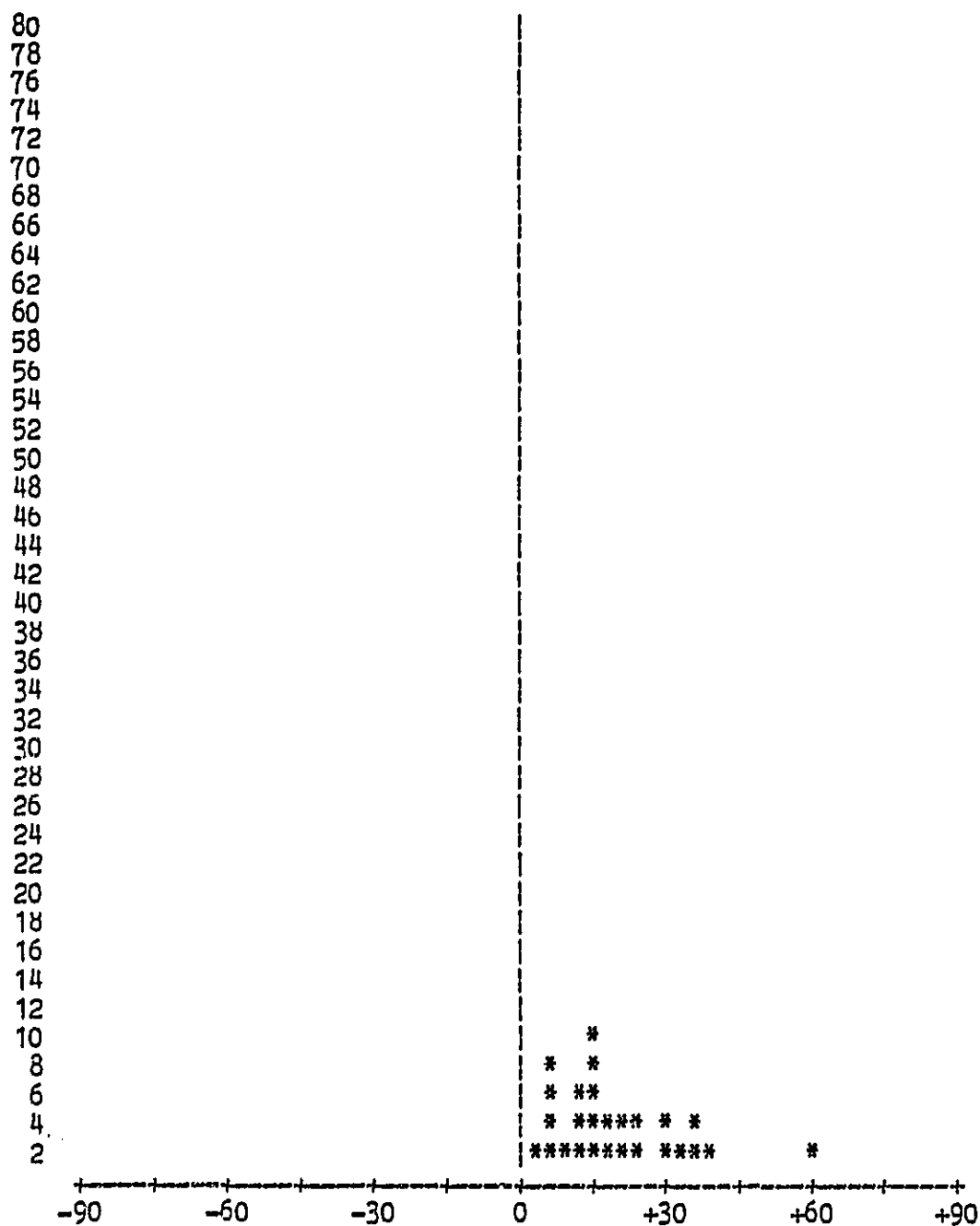
NUMBER OF OCCURRENCES BY DIFFERENCE

Parallel-Component Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN = -12.0212766
 VARIANCE = 218.488909
 MEAN (ABSOLUTE DIF.) = 15.0851064
 STANDARD DEVIATION = 14.7813704
 90% CONFIDENCE LIMITS -36.3366308 TO 12.2940776
 TOTAL OCCURRENCES = 47

CARRIER: RED DIRECTION: Westbound REGION: Polar



NUMBER OF OCCURRENCES BY DIFFERENCE

Magnitude of Vector Difference in Knots

Operational Segments MINUS AIDS Derived Segments

MEAN	=	18.9574468
VARIANCE	=	138.338615
MEAN (ABSOLUTE DIF.)	=	18.9574468
STANDARD DEVIATION	=	11.7617437
90% CONFIDENCE LIMITS	=	-3.390621595 TO 38.3055152
TOTAL OCCURRENCES	=	47

CARRIER: RED DIRECTION: Westbound REGION: Polar

Operational Segments MINUS AIDS Derived Segments

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RMS of Vector Error = 28.530048
TOTAL OCCURRENCES = 165

CARRIER: RED DIRECTION: Eastbound REGION: North Atlantic

Operational Segments MINUS AIDS Derived Segments

RMS of Vector Error = 21.911624
TOTAL OCCURRENCES = 327

CARRIER: RED DIRECTION: Westbound REGION: North Atlantic

Operational Segments MINUS AIDS Derived Segments

RMS of Vector Error = 23.8216755
TOTAL OCCURRENCES = 36

CARRIER: RED DIRECTION: Eastbound REGION: Polar

Operational Segments MINUS AIDS Derived Segments

RMS of Vector Error = 22.3097155
TOTAL OCCURRENCES = 47

CARRIER: RED DIRECTION: Westbound REGION: Polar